ELECTRICAL-MACHINERY ERECTION

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Journal of Electricity and Western Industry
Industrial Engineer

ELECTRICAL-MACHINERY ERECTION

BY

TERRELL CROFT

CONSULTING ENGINEER. DIRECTING ENGINEER OF THE TERRELL CROFT ENGINEERING CO.
MEMBER OF THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.
MEMBER OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
MEMBER OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
MEMBER OF THE AMERICAN SOCIETY FOR TESTING MATERIALS.
MEMBER OF THE ILLUMINATING ENGINEERING SOCIETY.

FIRST EDITION
THIRD IMPRESSION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK: 370 SEVENTH AVENUE
LONDON: 6 & 8 BOUVERIE ST., E. C. 4
1925

THE MAPLE PRESS COMPANY, YORK, PA.

PREFACE

This book deals with the mechanical—rather than the electrical—features of electrical-machinery installation. It describes the methods and processes which are, in modern practice, employed in the mechanical installation of electrical machinery, from the unloading of the apparatus from the car to its final fixing and aligning in its ultimate operating location.

It has been written from the practical man's standpoint—for the fellow who must install the equipment. The endeavor has been to convey the facts graphically, insofar as has been feasible. That is, illustrations (there are more than 300 of them) have been employed very freely to set forth the ideas which are presented.

The opening division discusses "Unloading And Moving Electrical Machinery." This is followed by "Supporting Electrical Machinery," which describes and explains how to arrange and construct wall, ceiling, and floor supports, and foundations for the machines. Next comes "Erecting Electrical Machinery;" in this division are considered the sequences and the methods which are employed in getting the unit (or its components) from the floor onto the supports and into position for final alignment. "Locating And Fixing" is then presented. It explains how the machine may be accurately established at proper elevation, leveled and aligned, and then permanently bolted or grouted. Finally, is a division section on "Mechanical Maintenance" which treats of the mechanical upkeep of electrical machinery; since the bearings are, from a maintenance standpoint, the most important mechanical feature, much of this section is devoted to this subject.

With this, as with other books which have been prepared by the author, it is the sincere desire to render it of maximum usefulness to the reader. It is the intention to improve the book each time it is revised and to enlarge it as conditions may demand. If these things are to be accomplished most

effectively, it is essential that the readers cooperate with us. This they may do by advising the author of alterations which they feel it would be advisable to make. Future revisions and additions will, insofar as is feasible, be based on such suggestions and criticisms from the readers.

Although the proofs have been read and checked very carefully by a number of persons, it is possible that some undiscovered errors may remain. Readers will confer a decided favor in advising the author of any such errors.

TERRELL CROFT.

UNIVERSITY CITY,
ST. LOUIS, MO.

ACKNOWLEDGMENTS

The author desires to acknowledge the assistance which has been rendered by a number of concerns and individuals in the preparation of this book. Among the concerns which cooperated in supplying material for illustrations are:

National Lead Co.
General Electric Co.
Westinghouse Electric Co.
Revolvator Co.
Diamond Rapid-Fire Drill Co.
Vibration Specialty Co.
S. K. F. Industries, Inc.
Allis-Chalmers Mfg. Co.
Midwest Steel & Supply Co.
Clements Mfg. Co.
Bristol Co.

Other acknowledgments appear throughout the book. If any has been omitted, it is due to an oversight and will, if brought to the author's attention, be incorporated in a future edition.

Special acknowledgment is hereby accorded to Daniel Staehle, Jr., *Electrical Engineer*, and Earl Bumiller, *Mechanical Engineer* of the *Terrell Croft Engineering Company* who have been largely responsible for the production of the book and who have assisted in every possible way since its inception.

CONTENTS

ELECTRICAL-MACHINERY ERECTION

DIVISION 1

UNLOADING AND MOVING ELECTRICAL MACHINERY

1. The Unloading And Moving Of Electrical Machinery becomes difficult only when the apparatus is relatively large and heavy. Machinery of less weight than about 150 lb. may usually be moved from place to place either by lifting, sliding,

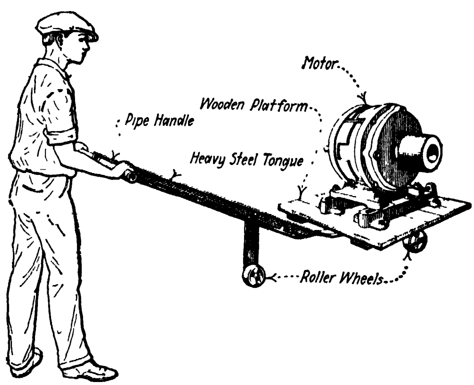


Fig. 1.—A homemade dolly truck for moving motors.

or on small hand trucks or dollies (Fig. 1). Larger and heavier apparatus, however, generally requires careful and special treatment, as is outlined in following sections.

2. Note.—The Manner In Which Electrical Machinery Is Generally Shipped is as follows: (1) *Small and medium-sized apparatus: motors, generators, and transformers* are generally crated or boxed and shipped in box cars; they are completely assembled before shipment. (2) *Very large motors, generators, and transformers* are generally shipped on flat cars. When the completely assembled machine is neither too

heavy for successful handling nor too large for the railroad clearances, it is often shipped in the assembled state. Otherwise it is shipped in parts. The machine or its parts is fastened to the floor of the car and if subject to damage by moisture, each is enclosed in a covered framework which is intended to shelter it from the weather. (3) *Switching and other control apparatus* is generally shipped in a partially assembled state. The parts are crated and packed into box cars for transportation.

3. All Machines Which Have Windings Must Be Protected From Moisture because moisture is very likely to be harmful to the insulation. Hence, when moving or unloading motors, generators, or the like, the machines should be covered with tarpaulin or some similar material whenever the moving or unloading is done during a rain or snow or whenever the machine will be left outdoors over night. If, at any time, a shower should blow up unexpectedly and wet a machine, damage usually may still be avoided by getting the machine under cover quickly and wiping off all surface moisture as thoroughly as is possible.

4. NOTE.—MACHINES WITH WINDINGS SHOULD BE PROTECTED FROM "SWEATING."—Sweating is due to the condensation of water vapor in the air upon the surface of a cold body. It is most likely to occur on an electrical machine when the machine is moved from a cold outdoors into a warm room. The sweating may sometimes be prevented by allowing the machine to remain for some time in a relatively cooler room, such as a corridor, before bringing it into the warm room. If sweating does occur, all surface moisture should be wiped off with a cloth and, if possible, an air current from fans should be played on the coils. Sweating will also take place in rooms the temperature of which varies widely (as when the rooms are heated only during the day). Hence, electrical machines should, preferably, be stored in rooms which have a fairly uniform temperature.

5. In Unloading Small Electrical Machines From Railway Cars Or From Trucks, they may readily be slipped or "skidded" along horizontal or sloping planks (Fig. 2). Frequently, a holding-back rope may have to be fastened to the motor when it is being lowered on a steep runway. It is important when unloading by sliding on planks, to insure that the center of gravity of the machine is kept well over the plank. Much damage may ensue if a machine is allowed to work its way to one edge of a plank and then fall off the runway. Assembled

motors and generators should be handled very gently to prevent damage to the shafts and other parts. Do not think that a crated machine can be rolled around at will without damage to the machine. Treat it carefully.

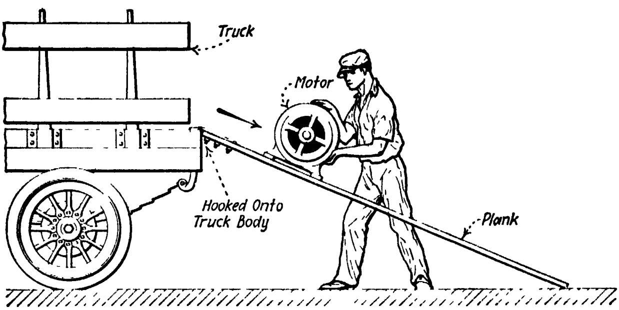


FIG. 2.—Unloading a small motor by sliding it down a plank.

Furthermore, if possible, avoid the use of hooks on crated machines.

6. NOTE.—IN MOVING SMALL MACHINES FROM PLACE TO PLACE, DOLLIES AND TRUCKS ARE USEFUL (Figs. 3 and 4).—These dollies and

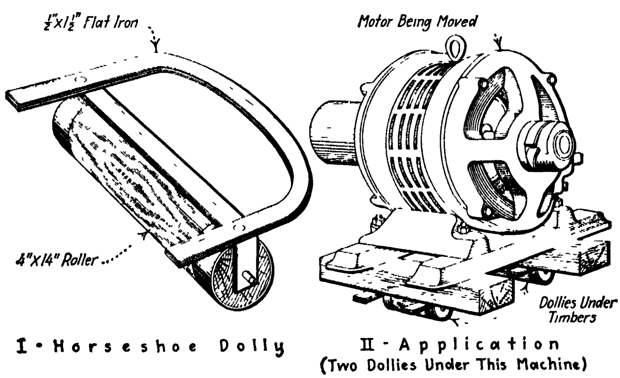


FIG. 3.—The horseshoe dolly and its use for moving small machinery.

trucks are relatively inexpensive and are very convenient. Although the wagon truck of Fig. 4 is more convenient to use than are dollies, there may be times when it is difficult to obtain a wagon truck. In such a case,

it is a simple task to improvise a dolly from pieces of pipe and some other scrap materials. The expedient of Fig. 5 may be employed in shifting a small or medium-sized machine over an obstruction.

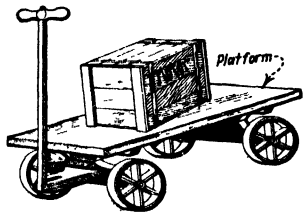


Fig. 4.—Wagon truck for moving relatively small machines.

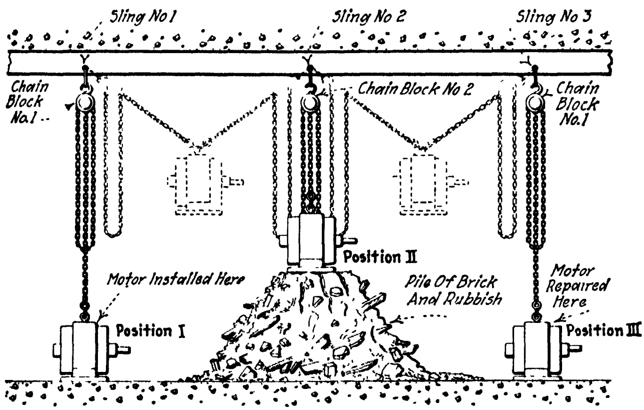


Fig. 5.—Moving a motor over an obstruction which extends the entire width of the building. Two chain blocks are required. Three sling positions are necessary, one of them directly over the obstruction. The illustration indicates the sequence of operations which are necessary to effect the shifting. (*Industrial Engineer*, Oct., 1923.)

7. Great Care Must Be Exercised In Handling Rotors Of Large Machines to insure that they are not damaged. The weight of a large rotor is often sufficient to crush its core laminations if the rotor is permitted to rest on them. The safest manner of supporting a rotor, while either moving or at rest, is by its shaft. The shaft may be supported from above by slings (Fig. 6) or from below by blocking (Fig. 7). Rotors may, in some cases, be lifted or supported at the laminations (Fig. 8) but protecting blocks and padding should then be

placed under the core laminations. *Never lift or support a rotor by the collector rings or by the commutator.* These parts are not of sufficient strength, usually, to stand the weight of the

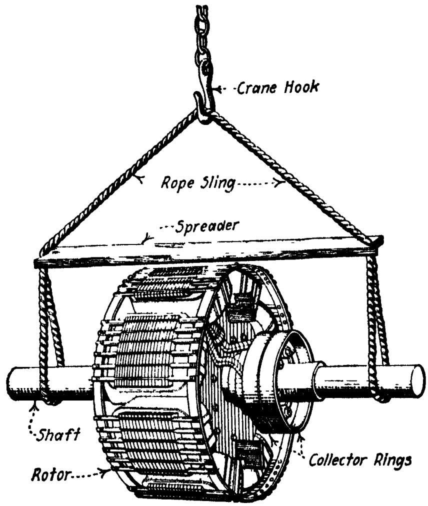


FIG. 6.—Rotor supported by a sling and spreader.

rotor. When slings are used, see that they do not bind against the collector rings, windings, or commutator; a spreader on top of the rotor (Fig. 6) will permit the slings to approach the

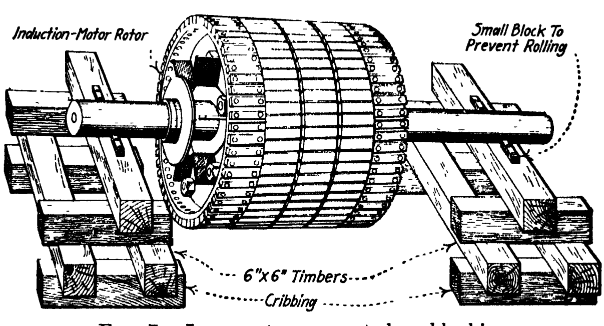


FIG. 7.—Large rotor supported on blocking.

shaft vertically. *Always support a three- or four-bearing rotor at the center* as well as at the ends of the shaft. Whenever shafts are supported at the journals (the parts which are to

revolve in the bearings) by wire-rope or chain slings, the shaft should be protected from abrasion by small pieces of clean wood placed as are the boards which protect the core in Fig. 8.

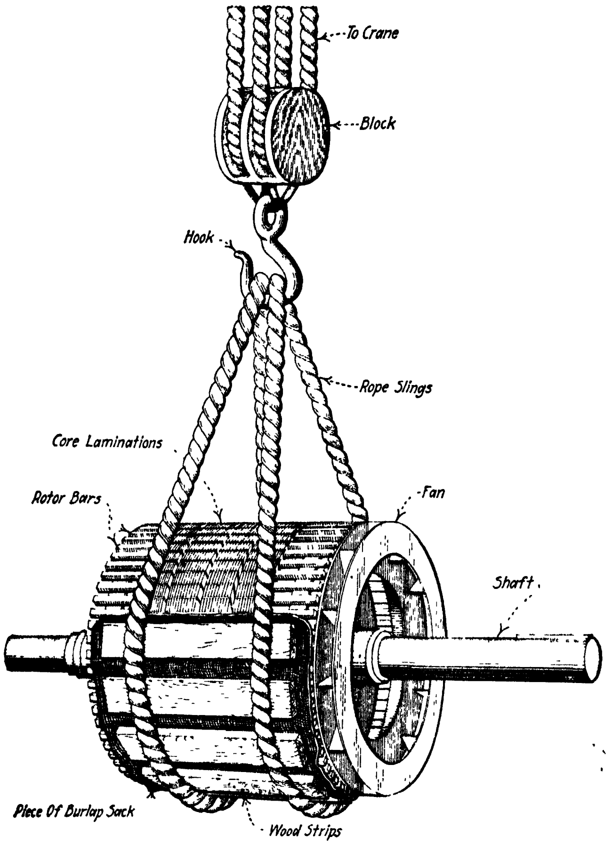


Fig. 8.—Showing how a rotor should be protected when a rope sling is used around the laminations.

8. Note.—Some Large Machines Have Rotors Made Of Solid Forgings —Such rotors may, of course, be supported and handled without exercising any of the above precautions, against damage tc the core laminations, because they have no core laminations. However, in all cases care must be exercised to avoid damage to the coil windings.

9. The Ideal Method Of Unloading Machines From Railway Cars is by means of a traveling crane. A machine part is

most readily lifted and moved by slings which are passed around the bottom of the part (Fig. 8). Motors and generators of small size (up to about 25 hp.) may be lifted by the eyebolts in their stator frames. Large machines, however,

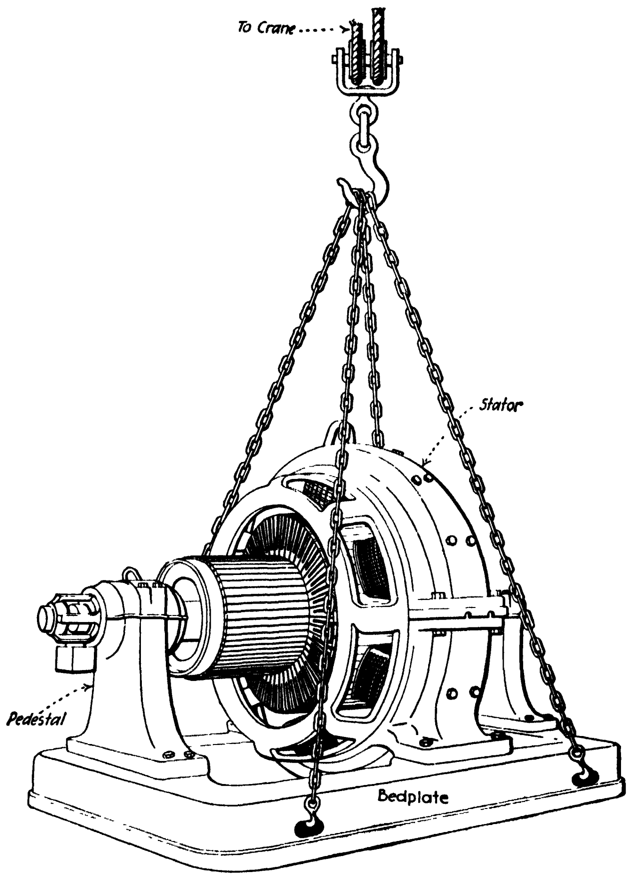


Fig. 9.—Showing how a small machine may be lifted with a crane. (Brush rigging and brushes removed.)

should never be lifted by the eyebolts. In a large machine the eyebolt is designed to carry only the weight of the stator or the top half of the stator. Whenever a machine has a bedplate, it is much safer to lift the machine by the bedplate

(Fig. 9) than to lift the assembled machine by the lifting eye (or eyes). Every modern transformer is equipped either with lifting eyes or hooks which will safely carry the entire weight of the transformer. Unfortunately, however, no crane is usually available at the place where the machines must be unloaded from the cars. Hence, in most cases, the unloading must be effected by more cumbersome methods, as explained in following sections.

10. NOTE.—WIRE ROPE IS GENERALLY CONSIDERED MORE SATISFACTORY THAN CHAIN OR MANILA ROPE for lifting machinery, although each has its advantages. If a chain is twisted slightly during the lifting of a given load, one or two links may be deformed or even cracked. Then the next time the chain is used for a heavy load, the deformed link is more highly stressed than are the remaining links. The excessive stress may then cause failure of that link. Hence, chains are often denounced as "treacherous." Wire rope, on the other hand, is not, generally, weakened so readily. A few of the outer strands of a rope will, usually, break and thus provide a visual indication of failure before the rope is materially weakened. Wire rope must be manipulated very carefully or its life will be very short. Short-radius bends are very destructive to wire rope; a sharp corner may cut the rope. Hence, in using wire rope, great care should be exercised to avoid short-radius bends and sharp corners.

11. It Is Important That The Proper Size Of Rope Be Selected For Lifting any machinery or other heavy part. When a rope is excessively strained, not only is it more liable to break than is one that is not so strained but its life is also materially shortened. If in doubt, it is better to employ a rope that is too large than one that is too small. The size of rope that should be used for a given load will depend considerably on its construction. Thus, the make up of the rope should be observed before it is employed for a heavy load. The safe loads for one type of manila and one type of wire rope are given in Tables 14 and 15.

12. NOTE.—A GOOD RULE FOR SELECTING THE PROPER SIZE OF ROPE for any lifting is this: Use a rope about two sizes larger than that which seems necessary. For example, if a 1-in. rope seems necessary use a 1½-in. rope. It is well, on any job, to have a good selection of slings from ½- to 1½-in. rope sizes.

13. NOTE.—MANILA ROPE Is satisfactory for rigging and for slings for light work. But for relatively heavy work, wire rope is much better.

Some erectors never use the same manila rope on two important jobs. They buy a new supply of this rope for each job.

14. Table Of Safe Loads Which Give Most Economical Wear And Breaking Loads For Three-Strand Manila Rope.

Diameter of rope, in.	Circumference of rope, in.	Safe load for most economical wear, lb.	Breaking load, lb.
½	1½	230	1,620
¾	2¼	520	3,640
⅞	2¾	775	5,440
1	3	925	6,480
1¼	3¾	1,445	10,120
1½	4½	2,085	14,600
1¾	5¼	3,070	21,500
2	6	3,600	25,200
2½	7½	5,630	39,400
3	9	8,100	56,700

15. Table Of The Approximate Strength And Proper Working Loads For Crucible Cast Steel Hoisting Rope.—These values are for rope composed of 6 strands, 19 wires to the strand with a hemp core.

Diameter of rope, in.	Circumference of rope, in.	Approximate strength, ton of 2,000 lb.	Proper working load, ton of 2,000 lb.
½	1½	8.4	1.68
¾	2¼	17.5	3.5
⅞	2¾	23.0	4.6
1	3	30	6.0
1¼	4	47	9.4
1½	4¾	64	12.8
1¾	5½	85	17
2	6¼	106	21.2
2½	7⅞	170	34
2¾	8⅝	211	42.2

16. *NOTE.—WIRE ROPE IS MADE IN VARIOUS TYPES AND OF DIFFERENT* GRADES OF IRON AND STEEL.—The values given in Table 15 apply only to the crucible cast steel rope of the construction indicated. Mild plow steel, plow steel, and improved plow steel wire ropes have a strength of approximately 14 to 16 per cent, 27 to 35 per cent, and 43 to 56 per cent, respectively greater than crucible cast steel ropes. When in doubt as to what type of rope you desire, write or ask the manufacturer what rope he recommends for the work you wish to do.

17. When Ordering Rope, It Is Always Desirable To State Whether The Specified Measurement Refers To Its Circumference Or To Its Diameter.—Riggers often specify the size of a rope by the length of the circumference in inches. Engineers, on the other hand, usually think of the size as the diameter in inches. By specifying, when ordering, whether you refer to the diameter or the circumference of the rope, delays and confusion will be avoided in the filling of the order. In this book the rope sizes which are given refer to the diameter.

18. The Correct Use Of Slings Is essential in the economical and safe handling of machinery. The following material is

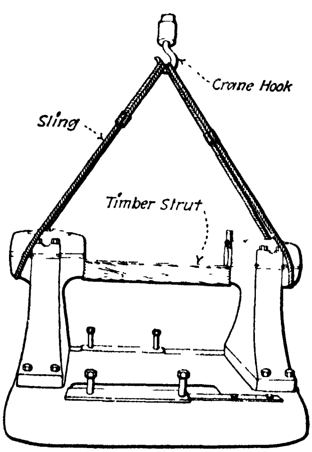


FIG. 10.—Proper method of bracing a two-pedestal bedplate prior to lifting. If a bedplate such as that shown is lifted, without first wedging the timber strut between the pedestals, an excessive strain may be imposed on the pedestals and on the bolts which hold them to the bedplate.

from "Direct-Current Motor And Generator Troubles" by T. S. Gandy and E. C. Schacht and outlines the essential principles:

19. *NOTE.—BEDPLATES WHICH HAVE PILLOW BLOCKS MOUNTED ON THEM SHOULD BE BRACED BEFORE BEING LIFTED, as shown in Fig.* 10. A long bedplate or one which has a light section should not be lifted by its pillow blocks until after a strut of timber has first been secured between their tops to prevent them from collapsing.

20. NOTE.—AS LONG A SLING AS IS FEASIBLE should be used to prevent undue stresses in the sling itself. The stress in a sling increases rapidly as the angle between the two legs of the sling increases. The

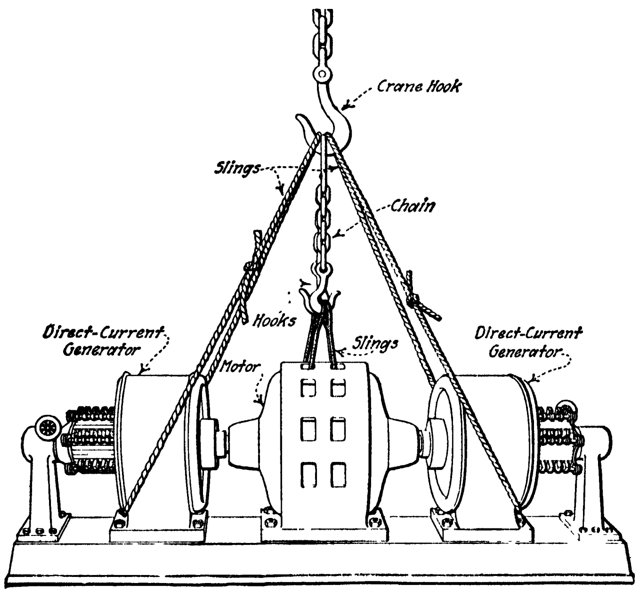


FIG. 11.—A correct arrangement of slings for lifting a small three-unit set.

proper application of a sling is shown in Fig. 11 which illustrates a much safer arrangement than that of Fig. 12.

21. NOTE.—WHEN EYEBOLTS ARE PROVIDED in frames or machine parts for lifting, the direction of pull of the sling on the eyebolt must always be along the vertical center line of the eyebolt. If it is not, a bending stress is produced in the bolt which may fracture or bend the eyebolt; this may occur even under a load which would be safely carried if it were applied properly. Where the proper—vertical—direction of pull on an eyebolt cannot be otherwise obtained, a spreader should be inserted between the slings.

22. NOTE.—WHEN LIFTING THE TOP HALF OF A DIRECT-CURRENT MACHINE, the sling is usually passed around the top frame between two

spools. Care is necessary to prevent slings from pressing against the spool windings or veneer flanges and damaging them. A thick, soft pad of canvass, leather, or similar material can often be employed effectively to prevent such damage. It should be understood, however, that such pads are not a certain preventive against damage. Unless great care is exercised, spools may be damaged by slings rubbing against them when turning the frame from a horizontal to a vertical position. One

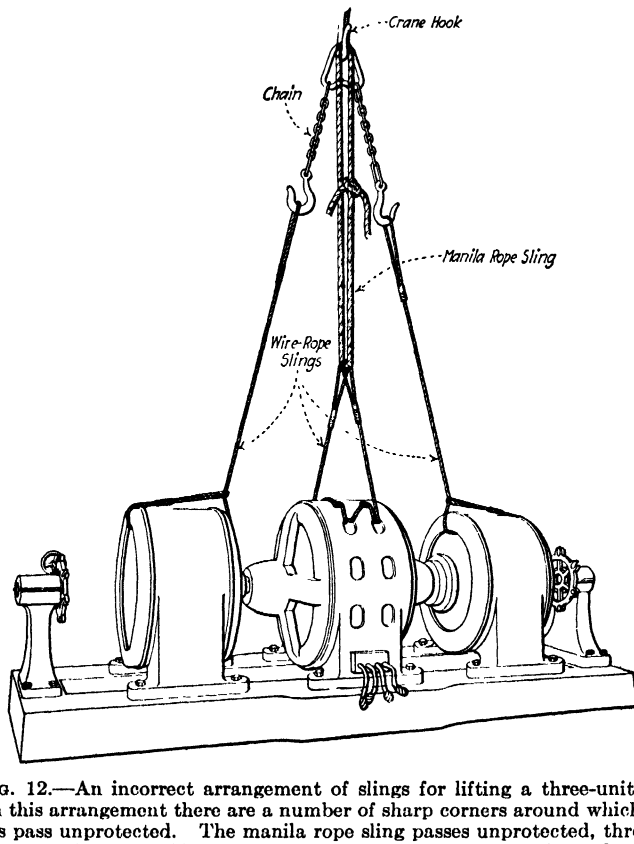


Fig. 12.—An incorrect arrangement of slings for lifting a three-unit set. With this arrangement there are a number of sharp corners around which the slings pass unprotected. The manila rope sling passes unprotected, through the loop of the wire cable. The arrangement of the outside slings does not insure an even distribution of the load.

sling arranged as in Fig. 13 is much safer than two slings arranged as in Fig. 14; the single-sling method is as strong as the two-sling one.

23. Note.—In Lifting Polepieces (Figs. 15 and 16) protective pads should be provided and the sling should, preferably, be doubled.

24. NOTE.—*A SINGLE SLING DOUBLED IS, ORDINARILY, PREFERABLE TO AN UNDOUBLED SINGLE SLING OR TO TWO SINGLE SLINGS.—Doubling* the single equalizes the strain in it and yet provides two strands to carry the load. Thus the arrangement of Fig. 17 is preferable to that of Fig. 18. Similarly, the one sling quadrupled of Fig. 13 is preferable to the two slings of Fig. 14.

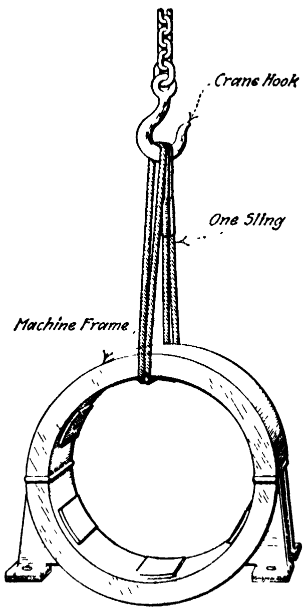


FIG. 13.—A single wire-rope sling so arranged that the load is carried equally by all four strands. This is the correct method.

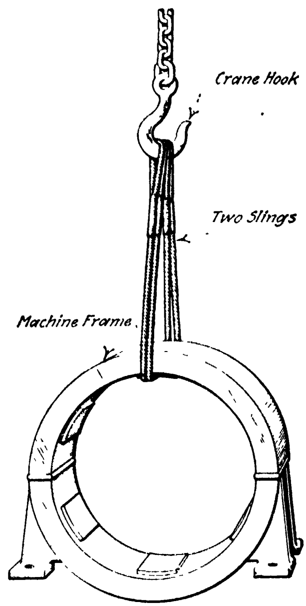


FIG. 14.—Two slings carrying a machine. The load on the strands will be unequal. This is an incorrect method.

25. The Unloading Of Large Machines From Railway Cars, when no crane is available, is usually effected by one of two methods: (1) *By rolling down a cribbed runway* (Fig. 19). This method is generally used only for machine parts weighing less than, say, 6 or 7 tons. (2) *By rolling onto a crib and then lowering* (Fig. 20); this method is used chiefly for parts weighing 8 tons or more. In either method, the machine is first bolted to skids (if skids were not attached before shipment) and rollers are placed under the skids. The

machine may then be rolled off of the car—either down the runway or onto the crib.

26. NOTE.—SKIDS should preferably be of some hardwood, such as oak or maple, especially if the machine will have to be moved a considerable distance on rollers. If the skids which are furnished under a heavy

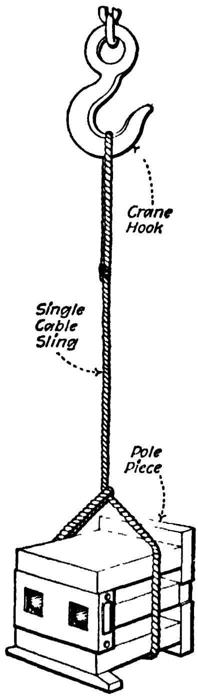


FIG. 15.—Pole piece being lifted with a single sling and without protecting pads. This is an incorrect method.

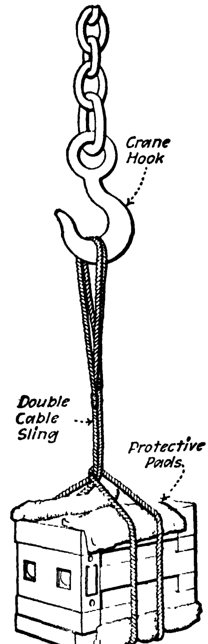


FIG. 16.—Pole piece being lifted with a double sling and with protective pads arranged to prevent damage to the laminations.

machine are of softwood, it often pays to place a hardwood shoe (a thin piece) under the skid. If it is known prior to shipment that a machine will have to be "skidded" a considerable distance, it will pay to specify to the manufacturer that "hardwood skids be supplied by him under the machine."

27. NOTE.—AN A-FRAME (Fig. 21) may often be improvised for handling machinery parts on jobs where there is no crane. The hoist support on the frame may be stationary or may be movable as shown in Fig. 22.

The movable support is the more desirable because when it is employed the part that is hoisted can be suspended directly over the place where it is to be set.

28. The Crib (Fig. 23) may be constructed of almost any lumber. But for best results good sound square-cut timbers should be used (railroad ties are not very satisfactory because they do not stack evenly). If square-cut timbers are not available, shingles may be used to shim up and thus provide a

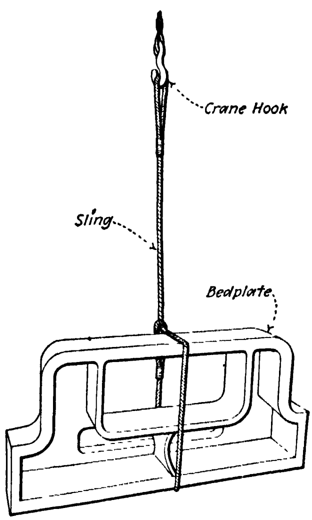


FIG. 17.—A single sling arranged for lifting a small bedplate.

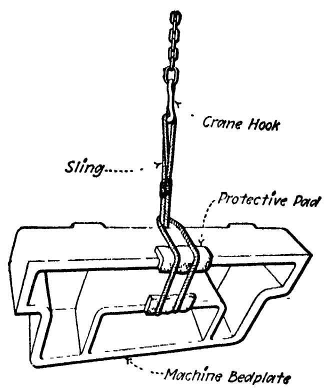


FIG. 18.—A single sling doubled arranged for lifting a small bedplate.

crib which will not "rock." The timbers should preferably be no smaller than 6 by 6 in. *Always use plenty of timbers.*

29. NOTE.—TO LOWER A MACHINE FROM A CRIB, the usual method is as follows: Beams A (Fig. 20) are placed in the crib at points where they may serve as supports for the four jacks, J, which are placed under the skids, S. The skids are then "jacked" off of the rollers and the rollers are removed as are also the uppermost beams, B, of the crib. The machine is then lowered with the jacks. All four jacks should be lowered simultaneously and at the same rate Just before the jacks reach the lower limit of their motion, beams C are moved in under the skids and, if necessary, blocks are used to fill any remaining space between the beams and the skids. Hence, by lowering the jacks a little more, the

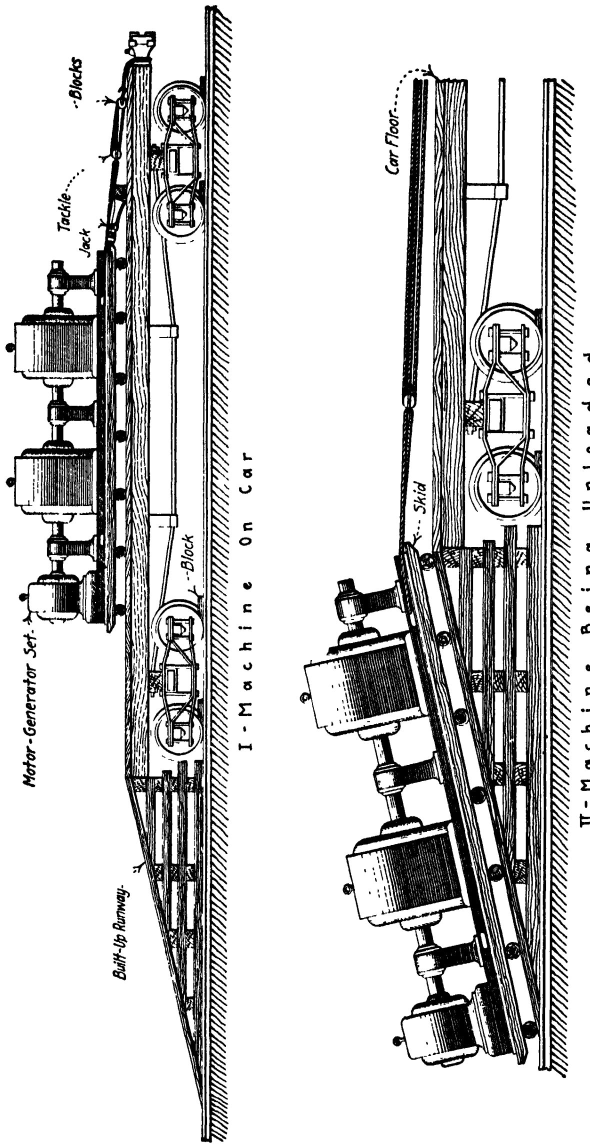


FIG. 19.—Unloading a large machine from a railway car.

skids are left resting on the beams *C* and the jacks may be removed. The beams *A* are then removed and placed at a lower point in the crib. The foregoing operations are then repeated until the jacks rest on the ground. Then, unless jacks with lifting toes at their bases are available,

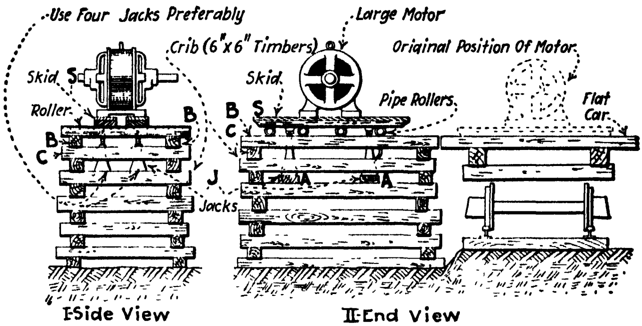


FIG. 20.—Unloading a large motor from a railway car by lowering on a crib.

pits must be dug for the jacks so that the machine may be lowered to ground level by the same method.

30. NOTE.—A MACHINE MAY BE LOWERED FROM A CRIB WITH ONLY TWO JACKS, OR EVEN ONE JACK, by alternately dropping one end

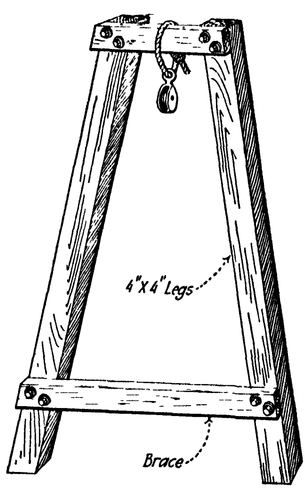


FIG. 21.—Illustrating an "A" frame used in erecting heavy machinery.

and then the other. First one end is let down about 3 or 4 in. and then the other end is lowered about twice this amount. Then the first end is again lowered about 6 or 8 in. and so on, until the machine has reached the desired elevation.

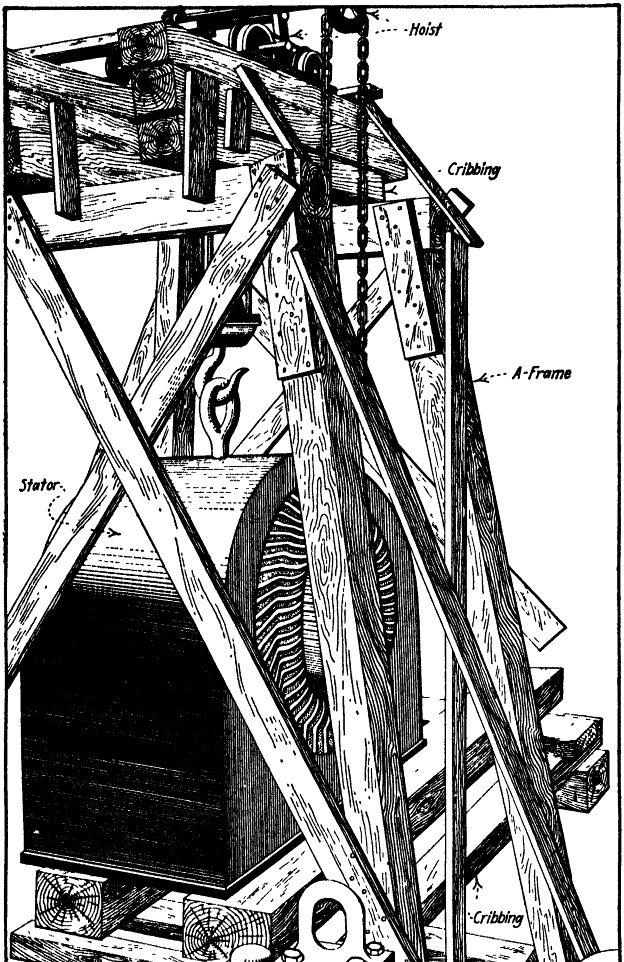


Fig. 22.—A large stator being lifted by means of an A-frame.

31. NOTE.—IN SELECTING JACKS FOR HANDLING MACHINERY (Fig. 24), the purpose for which the jacks are to be employed should be considered. Some erectors will not use a hydraulic jack (*whiskey jack*)

FIG. 23.—Stator of a large Westinghouse turbo-generator supported on rollers on top of a crib.

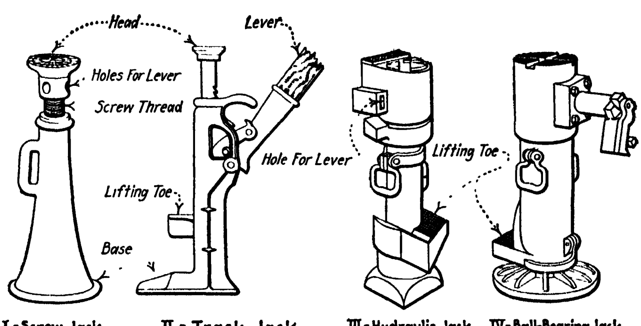


FIG. 24.—Four common types of jack which are used in erecting machinery. The ball-bearing and hydraulic jacks are the only ones that are suited to very heavy loads but are very expensive. The track jack is more rapid and more sufficient than the screw jack. The screw jack is cheapest and slowest.

because this type is considered "treacherous." When using hydraulic jacks, always protect the load by blocking up under it as it is raised. The

ball-bearing jacks are often preferred to those of the hydraulic type. For light work, the track jacks are satisfactory. Screw jacks are cheap and safe but they are slow.

32. A Gin Pole May Be Employed For Lifting And Lowering Electrical Machines, Or Their Parts Which Have Weights Of About 6 Tons Or Less (Fig. 25).—In rigging up such a pole, select a long stick for the pole and use it for nothing else. Its bottom end should be rounded. The head blocks and the guy blocks can be lashed securely to the top of the pole. Three

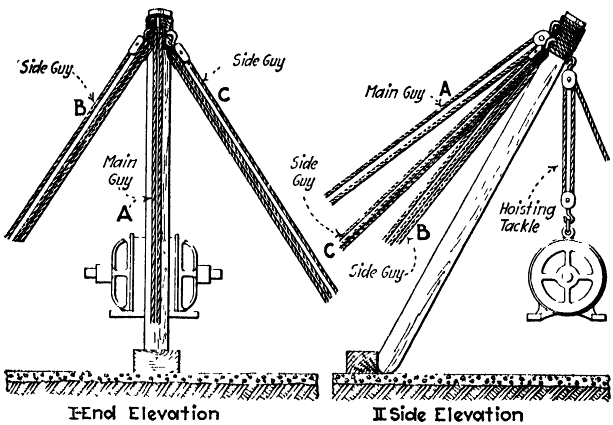


FIG. 25.—A gin pole employed for raising a motor.

guy blocks are generally required to make the pole stable. While the main guy, *A* (Fig. 25), would itself, if strong enough, prevent the load from pulling the pole over, a pole supported in this manner would be very unstable and could not be used. The side guys are needed to hold it in position. They also allow the load to be readily moved sideways (Sec. 33). The sizes of the blocks and ropes which should be used will depend on the weight of the load to be lifted. See Table 14 for the working loads for manila ropes.

32. NOTE.—A GIN POLE WILL COVER A SOMEWHAT LIMITED AREA; that is its top may be moved about, carrying the load with it, while its base is stationary. For example, a pole 16 ft. long, heavily loaded, may be moved to cover an area of about 5 ft. square. While this movement is not great, still it often is of much value.

34. When Moving A Load With A Gin Pole, The Guy Tackles Should Be So Arranged That They Will Not Be Overloaded.—Often the combined stress on the guy tackles is greater than that on the hoisting tackle. This stress increases as the angle, that the pole forms with the vertical, is increased, and also as the guys are shortened and approached more nearly the vertical. A minimum stress on all parts is obtained when the pole is vertical and the guys are as long as possible. The limit of the pole angle for a heavy load is about 30 deg. from the vertical. The angle between side guys, *B* and *C* (Fig. 25) should be about 90 deg. With the guys arranged as shown the load can be readily moved sideways by letting out on one side guy and at the same time taking in the same amount on the other; the main guy being held fast all the time. In moving the load in the direction of the pole it must be either raised or lowered as the case may be. To accomplish this all three guy lines, *A*, *B*, and *C* (Fig. 25), must be pulled in or let out at the same time. The two side guys, *B* and *C* together, should hold about as much as guy *A* does alone.

35. The Two General Methods Of Moving Machines From Car To Final Location are: (1) *By wagon or truck.* Modern trucks are capable of carrying loads up to 7 or 8 tons. Low-bottom wagons, horse or tractor drawn, may be used for loads up to about 15 tons. (2) *By rollers,* Sec. 36.

36. To Move A Large Machine On Rollers, the usual practice consists of first providing a smooth "runway" or surface for the rollers, next placing rollers under the machine, and then applying the necessary force to move the machine. When the surface over which it is desired to move the machine is soft, rough, or otherwise unsuitable for rolling, it is customary to lay parallel strips of board as a runway. Oak planks make a very satisfactory track for the rollers, the size being proportioned to the load—2- by 8-in. planks will do for light machines whereas 3- by 12-in. planks are none too heavy for big loads. By properly placing the rollers, the machine may be made to take what ever course is desired. Hard heartwood maple rollers 6 or 8 in. in diameter by 6 ft. in length are probably the most satisfactory; but *use plenty of them.* They may be bought from any machinery supply house. Four-inch or

larger steel pipe may be used in place of rollers but is not quite as satisfactory—the pipe is heavy, slips around on concrete, may break into concrete on heavy loads, and is too easily

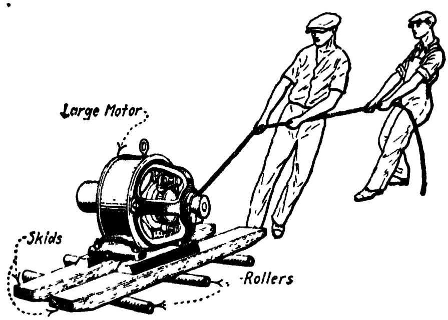


FIG. 26.—Moving a large motor on skids and rollers.

dented when struck with a hammer. The necessary force for moving the machine may be obtained in some cases with a jack (Figs. 19 and 24), sometimes merely by pulling on a rope

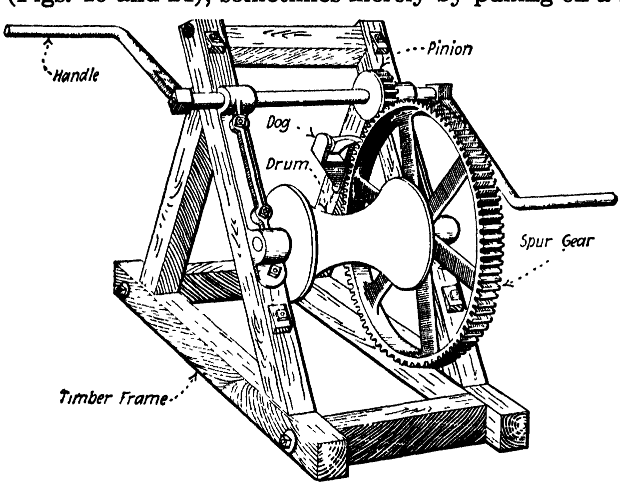


FIG. 27.—A portable geared winch with a concave drum.

(Fig. 26) and, where great force is necessary, by employing a winch (Fig. 27) either with or without tackle blocks.

37. NOTE.—A METHOD OF TRANSPORTING A LARGE TRANSFORMER is shown in Figs. 28 and 29. This was employed by the Pacific Gas and Electric Company in an instance where three 13-ton transformers, which

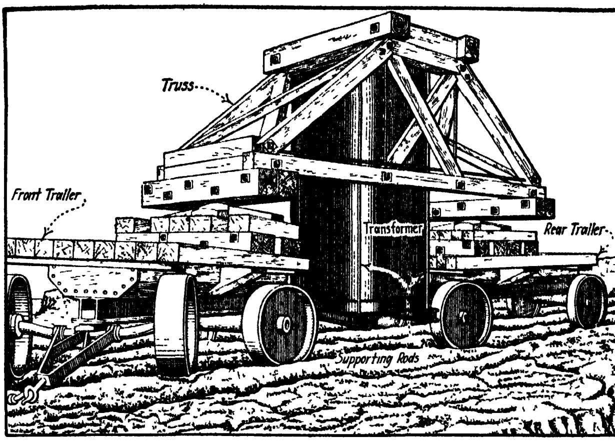


FIG. 28.—A large (13-ton) transformer being transported on trailers which were drawn by a tractor. The loading is such that the transformer remains in a practically vertical position regardless of road unevenness. See details in Fig. 29. (*Engineering News Record*, Apr. 12, 1923.)

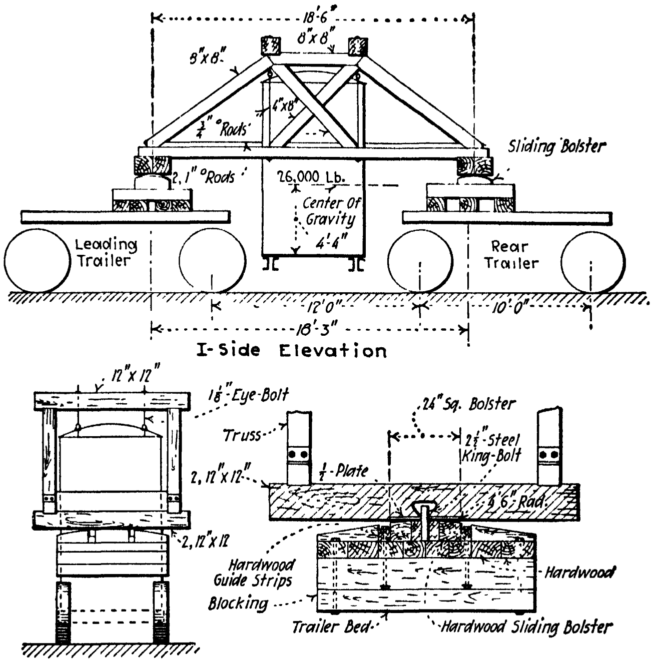


FIG. 29.—Details of transformer loading of Fig. 28. (*Engineering News Record*, Apr. 12, 1923.)

were 12 ft. high, had to be moved a distance of 14 miles over a mountain road. Because the transformers were delivered with the cores in place, they had to be kept in the vertical position. The illustrations (from *Engineering News Record*) are self-explanatory.

38. Attachment-Socket Floor Plates (Fig. 30) facilitate the moving of heavy equipment about the floors of electric

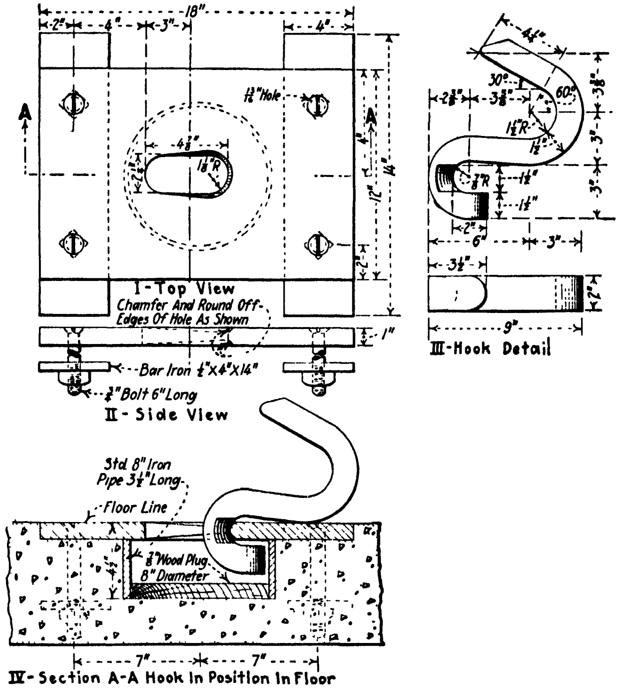


FIG. 30.—Attachment-socket floor plate and hook, to be set in electric station floors. (*Walter H. Millan, Electrical World*, Feb. 5, 1921.)

stations. In the floor of a recently built substation in St. Louis, steel hooks are inserted in special floor plates and the rigging and hauling ropes are passed around the hooks.[1] One of the floor plates, as shown in the detail drawing, is inserted in the concrete floor in front of each vault containing transformers or other heavy apparatus. The hooks are kept on hand in convenient places. The possible routes of each piece of apparatus which may have to be moved, have been carefully

[1] MILLAN, WALTER H., *Electrical World*, Feb. 5, 1921.

considered. Floor plates have been inserted at every turn or point where they may be of assistance in an emergency. The same arrangement is used for moving a transfer car, which runs on a track in front of the transformers, for the purpose of shifting in a spare transformer for one that is being taken out of service for repair or overhauling.

39. NOTE.—THE HOOK AND FLOOR PLATE shown in Fig. 30 are designed to withstand a pull of about 20,000 lb. The hook is made from a piece of 1½- by 2- by 20-in. bar iron. The material in one pull box consists of one steel plate 1 by 12 by 18 in., two pieces of ½- by 4- by 1¼-in. bar iron, four ¾- by 6-in. flathead machine screws and nuts, one piece of 8-in. standard iron pipe 3½ in. in diameter by ⅞ in. thick.

40. A Table Of Costs Of Loading And Unloading Machinery, which is based on an appraisal which was made before the war, is given below.[1] For large generators and motors assume the total shipping weight divided as follows: Rotor, 51 per cent; upper part of stator, 24 per cent; lower part of stator, 25 per cent. For motor generator sets assume the total shipping weight divided equally between the motor and generator.

Weight of piece, tons	Cost without crane, per ton	Cost with crane at railway station only, per ton	Cost with crane at power station only, per ton	Cost with crane at both ends, per ton
1	$11.50	$8 12	$3.45	$0.80
2	7 50	5.03	2.25	0.53
3	6 33	4.50	1.90	0 44
4	5.70	4.12	1.77	0.44
5	5.90	4.15	1.75	0.41
6	6.01	4.32	1.85	0.48
7	6.45	4.50	1.93	0.45
8	7.00	4.93	2.10	0.49
9	7.45	5.17	2.23	0.52
10	8.00	5.60	2.40	0.56
11	8.45	5.95	2 57	0.58
12	8.75	6.25	2.75	0.63

[1] From Gillette and Dana, "Handbook of Mechanical and Electrical Cost Data."

41. A Table Of Costs Of Hauling One-Piece Loads as determined by an appraisal which was made before the war, is given below.[1] For large machines assume the weights divided as in Table 40. For hauls over 20 miles in length over mountain roads, use average condition cost.

Weight of piece, tons	Flat country, good roads, cost per ton per mile	Average conditions, rolling country, cost per ton per mile	Mountain roads, cost per ton per mile
1	$0 40	$0 45	$0.50
2	0 35	0.37	0.40
3	0 35	0.40	0 46
4	0 36	0 47	0.57
5	0 38	0.55	0.70
6	0 40	0.62	0.62
7	0.42	0.68	0.93
8	0.44	0 74	1.04
9	0 46	0 80	1 13
10	0 48	0.86	1.24
11	0 49	0 90	1.31
12	0.50	0.93	1.34
13	0.52	0.95	1.38
14	0 54	0.98	1.42
15	0.55	1 00	1.54
16	0.56	1.02	1.47
17	0 58	1 04	1.50
18	0.60	1.06	1.52
19	0 61	1.07	1.53
20	0.64	1.09	1.55

42. NOTE.—THE COST OF LOADING, HAULING, AND UNLOADING small miscellaneous pieces will average, on the same basis as the above (pre-war prices), about the following amounts per ton per mile: (1) Flat country, good roads, $0.60 per ton per mile. (2) Rolling country, aver-

[1] From Gillette and Dana, "Handbook of Mechanical and Electrical Cost Data."

age conditions, $0.90 per ton per mile. (3) Mountain roads, $1.20 per ton per mile.

43. The Unpacking And Cleaning Of Electrical Machinery should be left until ready to set up the machines. Since these machines are usually packed so as to exclude moisture, and with the bright metal parts covered with a rust-preventive coating, it is unwise to unpack them or to wash the "slushing" from them until the machines are ready to be set up to run. Then, finally, the machines may be unpacked with an assurance of the least possible damage to them and with little likelihood of the loss of small parts.

44. When Storing And Handling Drums Containing Transformer Oil, be certain that the bungs are tight and remain so until the oil is used. Whenever possible store the drums indoors, in a dry, closed room. If the drums must be stored outdoors, lay them on their sides, with the bungs down. A cover will protect the drums from the weather and should be used when one is available. Never store the drums outdoors, end up, because water will collect on the head and may seep into the oil.

45. NOTE.—IF A DRUM OF COLD OIL IS TAKEN INTO A WARM ROOM, IT WILL "SWEAT."—To prevent moisture from entering the oil, the drum should be kept in the room long enough for it to reach the room temperature before the seal is broken.

QUESTIONS ON DIVISION 1

1. What are the general methods of moving small electrical machines from place to place?

2. How are electrical machines and apparatus packed for shipment?

3. In what way is moisture harmful to electrical machines? How may electrical machines be protected from the rain during moving? What should be done if a machine is caught unexpectedly in a shower?

4. What is the cause of *sweating?* How may it sometimes be prevented? What is the best treatment for electrical machines which have sweated?

5. State the usual methods which are employed and the precautions which should be observed in unloading small machines.

6. Draw sketches to illustrate the use of dollies and trucks for moving small electrical machines.

7. What precautions should be observed in handling large rotors with laminated cores?

8. Draw sketches to show three methods of supporting large rotors.

9. How should the rotors of three- and four-bearing machines be supported?

10. Is it safe to lift or support a rotor by the commutator or collector rings? Why?

11. Are there any limitations to the use of the eyebolts in the frames of motors and generators for lifting these machines? Explain.

12. What method would you employ for lifting a transformer with slings.

13. What is usually the safe procedure for lifting large rotative machines with slings? Draw a sketch.

14. State the relative advantages and disadvantages of chains and wire rope for use as slings. Which is generally considered the more satisfactory?

15. What sizes of wire-rope slings should one have on hand when preparing to move machinery? How should he select the proper rope for a given lift?

16. What are the two general methods of unloading large machines from railway cars? Draw a sketch to illustrate each. When, in general, should either method be employed?

17. How would you proceed about building up a crib? What kind of timbers would you use?

18. Of what kind of lumber should skids be made? What is meant by a *shoe* under a skid?

19. Explain the method of lowering a machine from a crib by using jacks. Draw a sketch.

20. Explain the method of lowering a machine one end at a time.

21. What are the two general methods which are employed for moving machines from the railroad to the place where it is to be set up?

22. About what weights can be transported by trucks and wagons?

23. Explain briefly the general procedure in moving machinery on rollers.

24. What kind of material is best suited for providing a smooth track for moving on rollers?

25. Of what wood are rollers made? What is a good size to use? Are these rollers better than steel pipe and why?

26. Draw sketches to illustrate a method of moving large transformers on trailers so as to maintain them in a vertical position.

27. Discuss the costs of unloading and moving machinery.

28. Should an electrical machine be unpacked as soon as it reaches the place where it is to be set up? Explain.

DIVISION 2

SUPPORTING ELECTRICAL MACHINERY

46. Electrical Machines Should Always Have Strong And Firm Supports to insure against: (1) *movement of the machine.* (2) *Vibration.* The support of any machine should be sufficiently strong that one may, after the support is built and the machine installed upon it, forget about it. In most cases, if sufficient material is employed rigidly to carry the load imposed by the machine, and the machine is securely fastened to this material, there need be no fear that the machine will shift after having been installed upon its support.

47. NOTE.—THE VIBRATION OF ELECTRICAL MACHINES is not generally a serious problem. These are purely rotative machines (all moving parts have only rotative motion about the axis of rotation) and should, if well made, tend to produce no vibration. The rotors of such machines can be almost perfectly balanced in the factory if the proper methods are employed. Hence, electrical machines should not tend to produce vibration. However, many people believe that electrical machines should have supports which have great weight so as to diminish the possibility of vibration. For this reason, small electrical machines are often set on heavy blocks of concrete or similar massive foundations which are much heavier than is actually required in most cases.[1] Although heavy foundations usually are not necessary, still the foundation must be rigid enough to prevent the vibration of the machine which may be produced by external causes. Such vibration may be, and often is, transferred from the driven or driving machine to the motor or generator. Even slight vibration will ultimately shorten the life of the insulation and bearings and cause trouble with the commutator and slip rings, although the machine may, apparently, give good service for some time. Thus, vibration should, if possible, always be avoided. Machines which have a capacity in excess of 50 kw. should be supported on solid masonry or concrete foundations—but these need not be large or extra heavy. Weight is only indirectly necessary.

[1] See the author's "Machinery Foundations And Erection," for a further discussion of the vibration of machinery.

48. Electrical Machines Should Be Located Preferably in places which are cool, clean, light, dry, and accessible. If the place is hot, the machine must be rated more liberally. If it must be in a dirty place, total or partial enclosure should be employed, because dirt may cause a failure. If moisture or fumes are present, the motor should be protected, as much as possible, and the insulation specially treated to meet the conditions; isolated motor rooms are desirable in such cases. Accessibility is desirable so that their will be no tendency to neglect the machine. Adequate space should be provided for the repair of the machine and the removal of parts. On important machines, ready means should be provided for handling the machine and its components.

49. Generators, Large Motors, And Two-Unit Electrical Machines Are Generally Placed On Foundations Or Floor Supports.—Inasmuch as such machines are usually located in engine-rooms or motor-rooms (rooms purposely set aside for the housing of such machines), the locations of the machines within the rooms are generally so planned as to make attendance to the machines and their repairs as convenient as possible. The most convenient place to have a machine, when working on it, is obviously near the floor. Furthermore such machines are often very heavy. Hence they require very substantial supporting members which are much more expensive to build the farther they are extended from the ground. Considerable cost can usually be saved, therefore, by locating these heavy machines on the lowest floor of a building where they may be supported on individual concrete or masonry foundations. Advantage is thereby taken of the supporting power of the underlying soil (or rock).

50. NOTE.—THE FOUNDATION OR SUPPORT OF THE MACHINE SHOULD PROJECT A LITTLE ABOVE THE FLOOR so that the machine will be above the dirt and moisture that are often present on the floor. When a high bedplate is employed, its lower edge may be on the same level as the floor, since the thickness of the bedplate will elevate the machine to a safe distance above the floor.

51. Small Motors Are Often Placed Elsewhere Than On Floors.—(By the term "small motors," as employed herein, is meant such motors as are used in shops or industrial plants for

driving individual machines or groups of machines. Their size may range up to 30 or 50 hp., or in some cases they may be even larger than this.) These motors are generally placed where they will not occupy space which is otherwise useful. Since floor space in factories and shops is very valuable for manufacturing purposes, the motors in these applications are usually supported from walls, ceilings, columns, or from some of the driven machines. These supports are explained in detail in following sections.

52. Note.—The Advantages And Disadvantages Of Overhead Supports For Motors are as follows: (1) *Advantages.* Motors on overhead supports occupy no valuable floor space; the motors and their drives need not be guarded against accidental contact and against getting caught in the drive mechanism; the motors present less electrical hazard to machine operators in case of electrical trouble in the motor. Furthermore, machine operators "feel" safer when farther removed from the motors and can therefore do more and better work. (2) *Disadvantages.* Unless careful supervision is employed, overhead motors are liable to suffer through inadequate attention—cleaning and oiling. They are not as accessible and usually require more time to repair and install.

53. Electric Machines For Belt Drive Should Be Arranged To Slide On Bases Or Rails (Figs. 142 and 149).—Such bases or rails are generally furnished by the manufacturers of the machines. They serve to provide means for tightening the belt without having to move the machine on its support and without shortening the belt. When installing machines on slide rails or bases, care should be taken so to arrange the bases or rails that the tightening screws serve to increase the distance between the pulley centers (there is a right and a wrong way to install the bases). However, a machine which has a tightening bolt that fastens underneath the machine and that holds it in both directions, may have its base installed either way. The preferred manner is so to arrange it that tightening the bolt increases the distance between the pulley centers.

54. Note.—An Unbelted Electrical Machine Should, Preferably, Be Provided With A Bedplate Or Soleplate (Fig. 168) so as to distribute the weight of the machine over greater area than is provided merely by its feet. Bedplates and soleplates insure against uneven settling by furnishing a rigid support for the motor feet. Often,

the bedplates or soleplates afford a very convenient means for leveling and aligning electrical machines (Sec. 391).

55. The Fundamental Requirements Of A Foundation Or Floor Support are, briefly: (1) *To provide a firm and solid support for the machine* so that it will not settle or otherwise move under the influence of its weight or any other forces which may act on it. (2) *To provide sufficient mass* (weight) *or rigidity to prevent excessive vibration* of the machine, provided the machine is unbalanced or is acted upon by unsteady forces. (For a thorough treatment of foundations and floor supports the reader is referred to the author's "Machinery Foundations And Erection.")

56. Particular Attention Should Be Given To The Construction Of Motor Supports.—If the support is of wood, the timbers should be rigid and all bolts tight. Otherwise vibration will occur. This will result in motor and in belt trouble. For floor mounting, the top of the foundation should be at least 8 in. or 1 ft. above the floor level. This is to prevent injury to the motor by water when the floor is scrubbed, and by dirt when sweeping. It will also render the motor more readily accessible for inspection and repairs.

57. A Good Form Of Concrete Floor Support is shown in Fig. 31. The support, or foundation, consists of a square concrete prism. Although a foundation which has sloping sides presents a very pleasing appearance and gives an impression of extreme stability, the construction of such a support is considerably more expensive than that of a similar one having vertical sides. To construct the forms for the concrete for a sloping-side foundation requires much more skill and time than for one with straight sides.

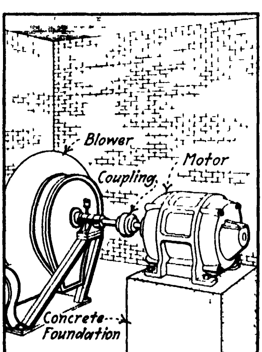


Fig. 31.—A concrete motor support extending upward from the floor.

58. Note.—Where Small Motors Need Not Be Raised Above Floor Level, They May Be Fastened To Concrete Floors With Expansion Bolts or other anchored bolts (Fig. 32). The bolts may be anchored by pouring cement grout, molten sulphur, or molten lead into the drilled holes or by the use of some other suitable means of anchorage. It is preferable to support the

motor at a short distance above the floor for the reason given in Sec. 50. Railings (Fig. 33) should be installed around the motor.

59. NOTE.—IN BUILDING CONCRETE FOUNDATIONS the anchor bolts if cast in the foundation must be accurately located. Templets are often employed for properly locating the bolts. In order to permit a slight

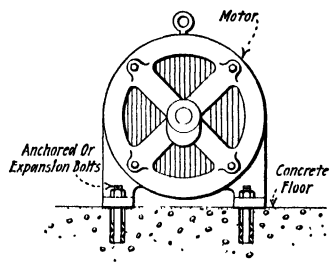


FIG. 32.—Simple method of fastening motor on concrete floor.

variation in the position of these bolts, it is advisable to locate them in iron pipes embedded in the foundation and of somewhat larger internal diameter than the bolts themselves. It is also advisable to provide anchor-bolt pockets or openings in the large foundation which give access to the nuts at the lower ends of the bolts.

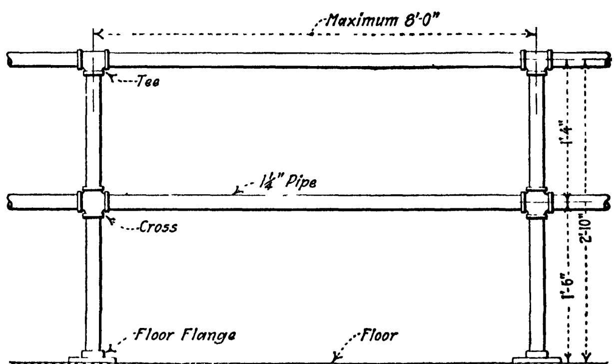


FIG. 33.—A pipe railing for motors.

60. To Support An Electrical Machine At A Slight Elevation Above The Floor, wooden or structural-steel beams may often be employed (Figs. 34 and 35). Steel supports are preferable, especially in damp places, because steel supports have much longer life under such conditions. Furthermore,

steel supports are usually more rigid than wood and are therefore desirable, especially where extreme rigidity is required, as they reduce the amount of vibration of the machine. Wooden beams are often employed primarily

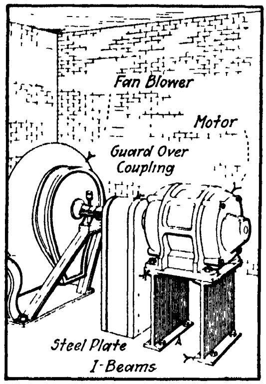


Fig. 34.—A steel floor-support for a fan motor.

because they are easily worked and are usually readily available. In most small installations they are fairly satisfactory.

61. Note.—Wooden Timbers May Be Used For Temporary Floor Supports (Fig. 36) even when no means for securely fastening

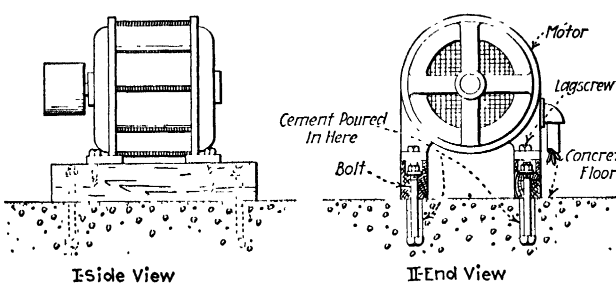


Fig. 35.—Method of supporting a motor at the floor on wooden beams.

down the timbers is available. In the case illustrated, an old motor was erected to supply power for driving a belt-driven mill after the steam engine (which constituted the regular drive) had to be stopped for extensive repairs.

62. Small Motors May Often Be Installed On Concrete Floors as shown in Fig. 37. The surface of the floor is covered with a 1-in. layer of special, proofed felt to absorb vibration, the edges of which are treated with three coats of paint as a preservative. A 6-in. slab of concrete, with channels and

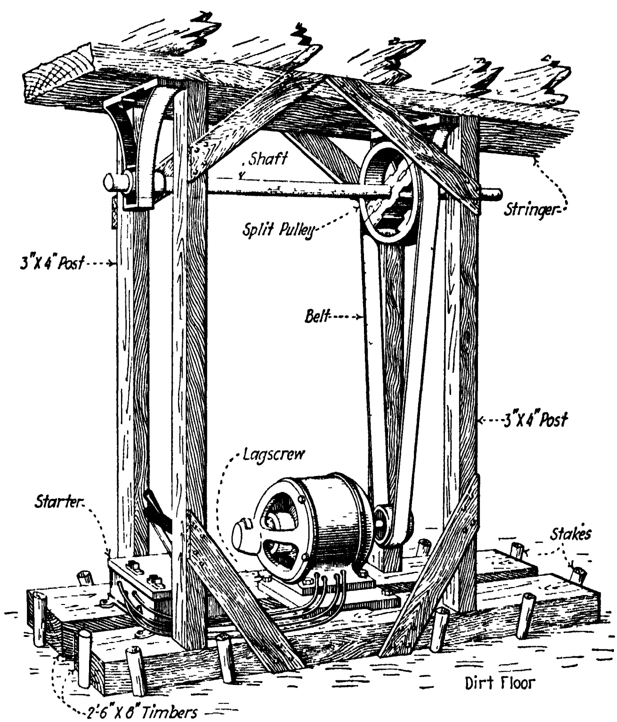


FIG. 36.—Showing how a motor was temporarily set up on a dirt floor under a lineshaft.

angles cast in it, is laid on top of the felt. The bolts are inserted through holes in the concrete and channels which are bushed with $\frac{1}{8}$-in. felt to prevent transmission of vibration. Felt pads are provided also under the anchor plates. Where no trouble from the transmission of vibration is encountered, no felt or isolation material is required.

63. Note.—Where The Transmission Of Vibration Gives Serious Trouble, springs are often installed under the motor support. Sand, cork or other isolating material may also be employed. See the author's "Machinery Foundations And Erection" for a discussion of vibration transmission and its prevention.

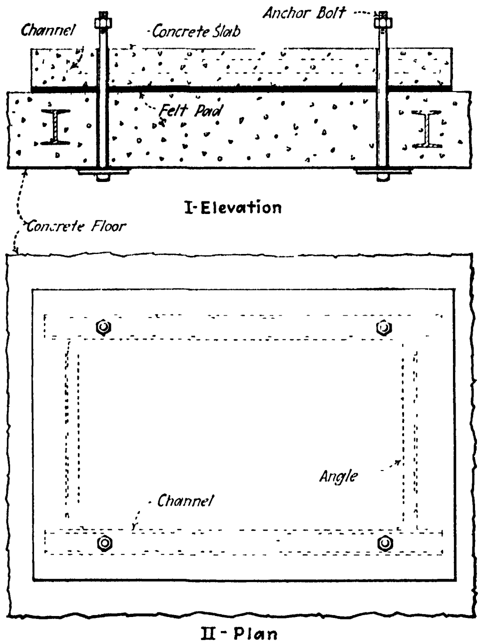


Fig. 37.—Isolated concrete-slab foundation on a concrete floor.

64. A Motor Of Small Size May Be Fastened To A Wall in one of two ways: (1) *With its base against the wall in a vertical plane* (Figs. 38 and 39). (2) *On a platform or bracket supported from the wall* (Figs. 40 and 41). Fastening the motor directly to the wall is the cheaper construction and usually provides the stronger support. The disadvantages of this construction are that the motor is more difficult to level and align when its base is in the vertical plane, and that the motor is more inaccessible, which renders repair and inspection difficult. The tendency under such conditions is to neglect the motor. The consequence is that the life of the motor may be materially

shortened. The platform method, while somewhat more expensive in first cost (in that it involves the making of a

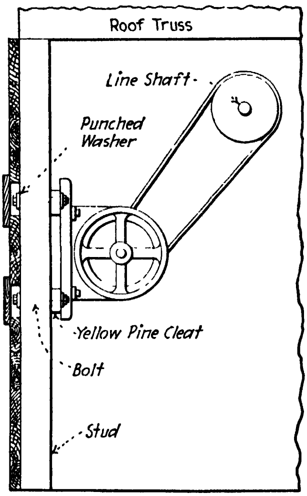


FIG. 38.—Showing a simple method of supporting a motor on a frame wall. The wooden covers over the outside bolt heads protect them from rain and snow.

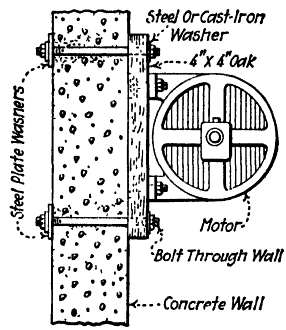


FIG. 39.—A suitable method of mounting a motor on a concrete or brick wall.

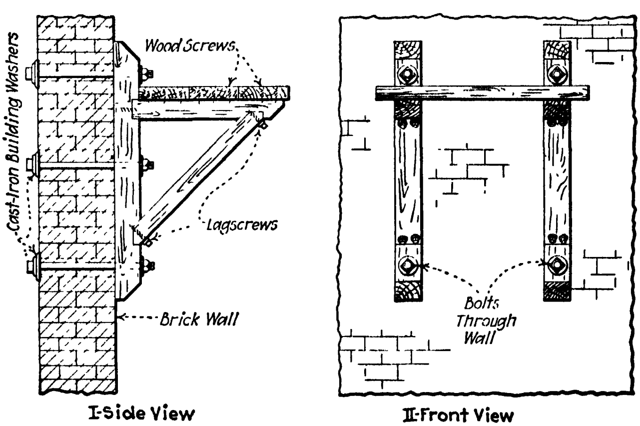


FIG. 40.—A simple bracket for supporting a motor on a brick (or other) wall.

bracket), is usually the more desirable one. As previously stated, it renders repair and inspection of the motor more

convenient. Thus it will generally pay for itself either in the added life to the motor or in the time saved in motor maintenance.

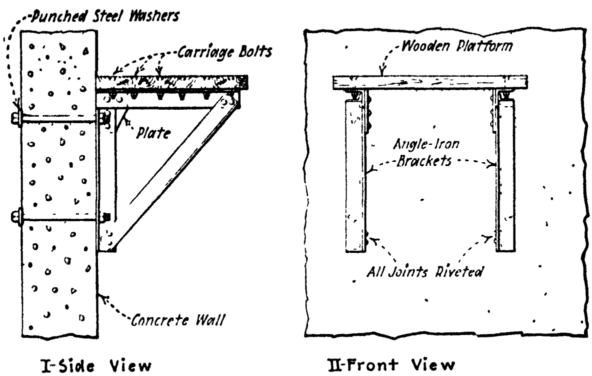


FIG. 41.—A simple but very rigid wall support made of structural-steel angles.

65. A Motor Mounted With Its Base Toward The Wall produces a bending moment in the wall. Judgment must be exercised in mounting the motor to ascertain that the wall will be strong enough to withstand this moment. Usually, it is not desirable to mount a motor larger than 25 hp. on the wall in this manner unless the wall is very strong or is reinforced. A heavy motor often may be mounted on the wall provided long beams (either of wood or steel) are bolted vertically against the wall to distribute the load. Small motors (Fig. 42) may be bolted to brick walls with bolts grouted or anchored in the wall, but large motors certainly must be provided with bolts that extend through the wall. The bolt washers on the outside of the wall (Figs. 38 and 39) should be of ample size to distribute the load properly.

66. NOTE.—WHEN THE MOTOR IS ERECTED WITH ITS BASE IN A VERTICAL PLANE, the end bells or bearing brackets must be rotated through 90 deg. so that the bearings will be properly lubricated (Sec. 203), unless the motor is specially built for running in the vertical position. Some motors cannot be installed in any but the upright position.

67. Mounting A Motor On A Bracket Fastened To The Wall also produces a bending moment in the wall, which the wall must be strong enough to resist safely. When the bending stress is too great for the wall, the platform can be arranged as explained in the following note. It is evident that the bracket itself (Figs. 40 and 41) must be made sufficiently

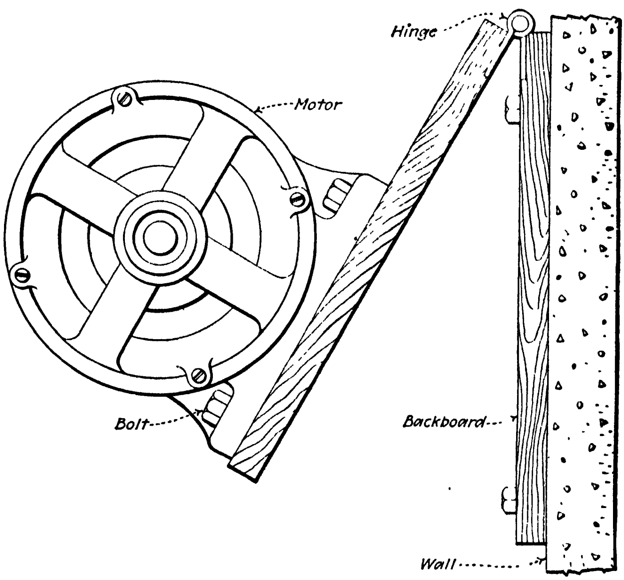


FIG. 42.—Mounting which was successfully used for a motor for belt driving a small bench lathe. The motor has a cone pulley. A bolt tightener is unnecessary. The belt tension remains practically constant. "The shifter rod is placed over the lathe in the usual convenient position, extending to the left where it enters a box which contains a double-throw reversing switch. Moving the rod to the left starts the lathe in forward motion. Moving it to the right causes it to reverse." (A. W. Forbes in *American Machinist*, Feb. 1, 1923.)

rigid to carry the load. Either wooden or steel brackets may be used. The steel brackets have the advantage that they are more rigid and fireproof. A strong and neat-looking bracket, which is also comparatively economical, may be made of structural-steel angles (Fig. 41). It is customary to place a

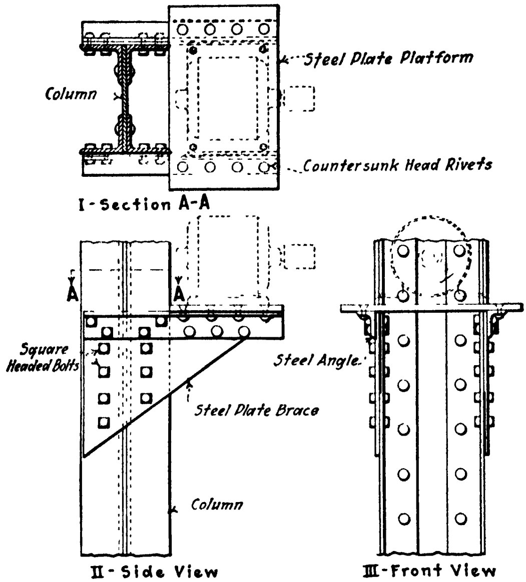


FIG. 43.—A structural-steel motor bracket attached to a structural-steel column. The same kind of bracket might be attached to a wooden column with lagscrews or to a reinforced-concrete column with expansion bolts.

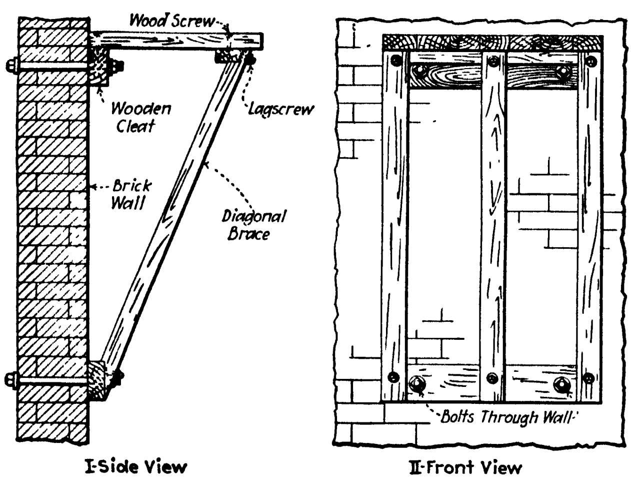


FIG. 44.—A wall bracket with a long diagonal brace to reduce the stress on the wall.

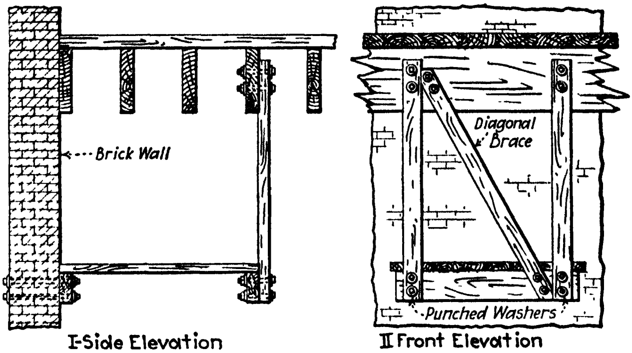


FIG. 45.—Motor shelf supported from wall and ceiling.

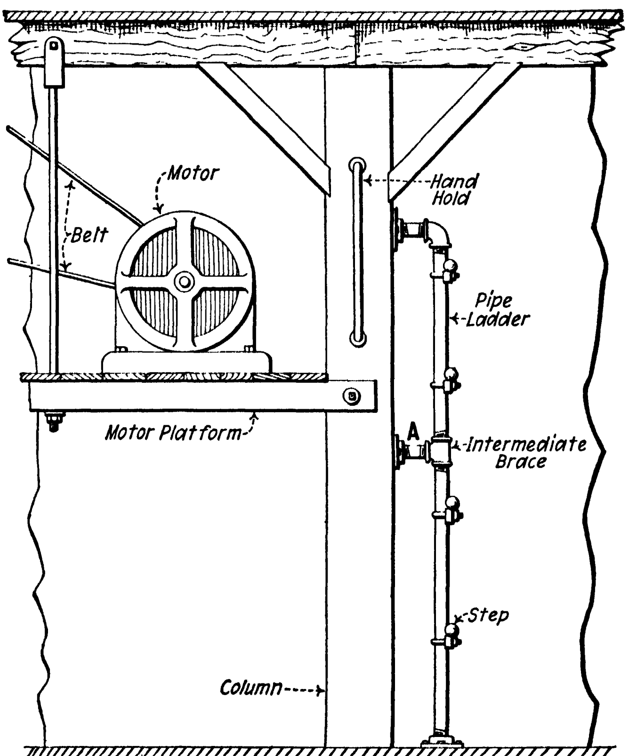


FIG. 46.—A pipe ladder to a motor platform. Elevation detail shown in Fig. 48.

matched wooden floor on the brackets and bolt the motor to this. On some installations, sheet steel floors (Fig. 43) are used because they are fireproof, but they have their disadvantages (Sec. 84).

68. Note.—The Wall May Be Relieved Of Some Of The Bending Stresses by one of several arrangements. By decreasing the angle which the diagonal braces make with the wall, the bending stress in the wall is reduced. Thus when it is desired to reduce the stress in the wall, the diagonal braces should, instead of being made at the usual angle of

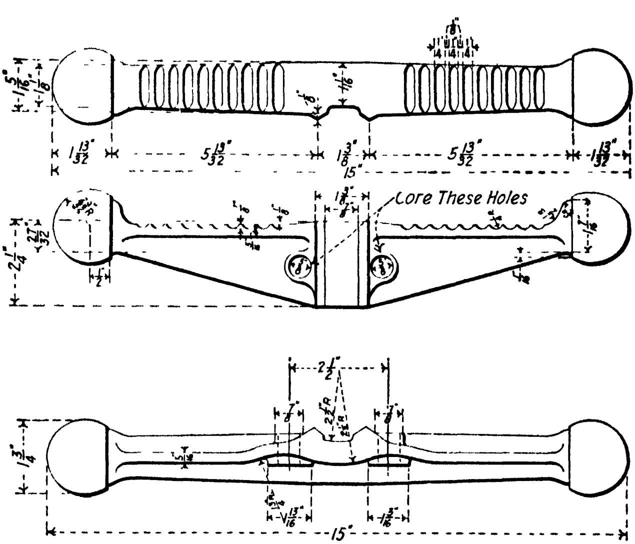


Fig. 47.—Detail of step used on ladder shown in Fig 48.

about 45 deg. with the wall, be made very long in proportion to the length of the horizontal members (Fig. 44). Also, by supporting the outer end of the platform from the ceiling (Fig. 45) or floor, the bending stress on the wall may be minimized.

69. When Building A Bracket Or Platform For a Motor, it is desirable to make it large enough to allow a man to get around on all sides of the motor. At least 1 ft. of space should be provided on each side of the motor. The installation, whenever possible, of fixed ladders (Figs. 46, 47, 48 and 49) leading

to the platforms, will save considerable time in inspecting the motors and they will be worth their slight cost.

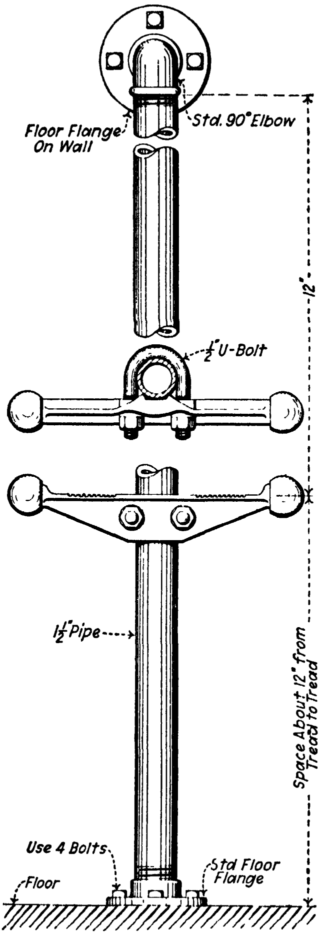


FIG. 48.—Elevation detail of the pipe ladder shown in Fig. 46.

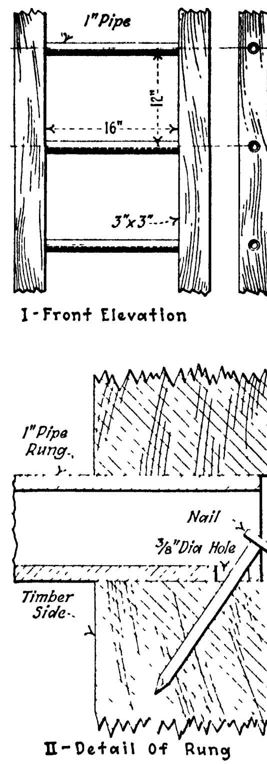


FIG. 49.—Construction of a ladder with pipe rungs.

70. NOTE.—PLATFORMS BUILT ONTO WALLS OR COLUMNS are usually convenient locations for motors. The column or wall provides a good support for attaching a fixed ladder to the motor (Fig. 46). It is also handy for locating the starting device or switch.

71. Electrical Machines May Be Mounted On Columns, vertically as shown in Fig. 58, or they may be built onto brackets which are fastened to the columns (Figs. 50, 51, 43 and

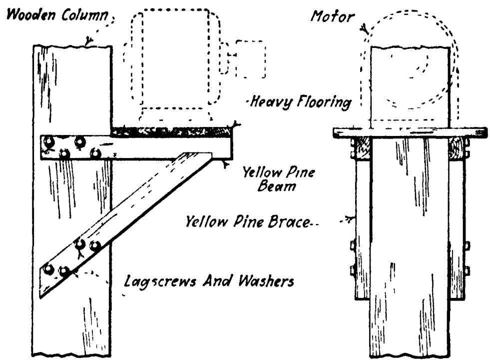


FIG. 50.—A simple wooden column bracket.

others). Columns, like walls (Sec. 65), are not usually designed to stand great bending moments. A column which is

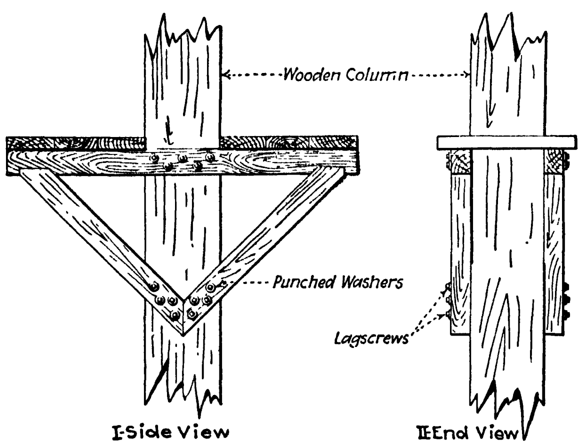


FIG. 51.—Wooden column support for two motors. This arrangement is somewhat better than having but one motor mounted on a column (as in Fig. 50) because it tends to relieve the column of bending stresses.

already subjected to a great axial (compressive) load will not stand much bending force before it will begin to "buckle."

Hence, care should be exercised in mounting motors on columns, that too great a bending moment is not thereby intro-

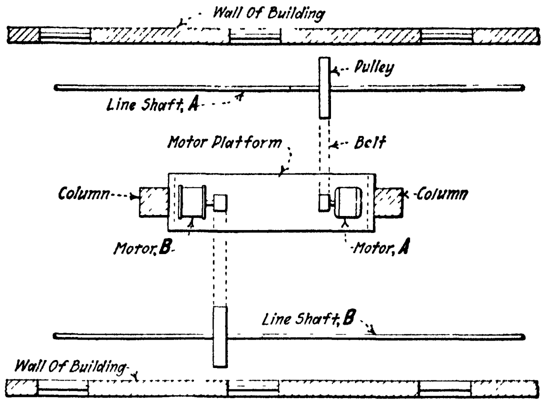


FIG. 52.—Motor platform, for two motors, mounted between columns.

duced in the column. If a motor is supported by a single column (as in Figs. 50 and 43), the motor should be placed as

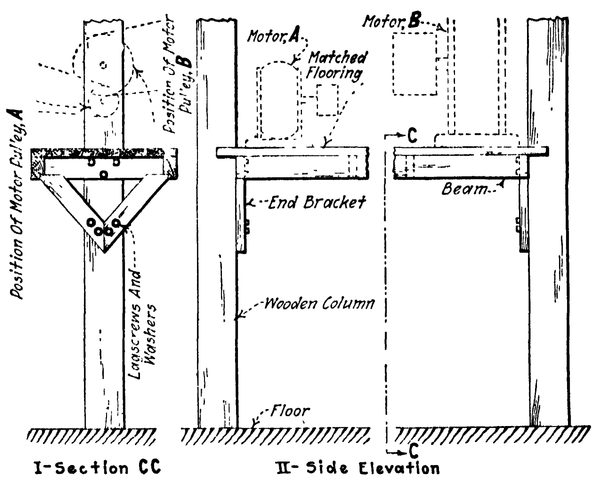


FIG. 53.—A wooden platform for two motors between columns. (Details of the support indicated in plan in Fig. 52.)

near to the column as is possible. The nearer the motor is toward the column the less will be the moment introduced in the column.

72. Note.—Columns Which Bear The Load Of Machines May Be Relieved Of Most Of The Bending Stresses in one of three ways: (1) *Two similar machines may be mounted on opposite sides of the*

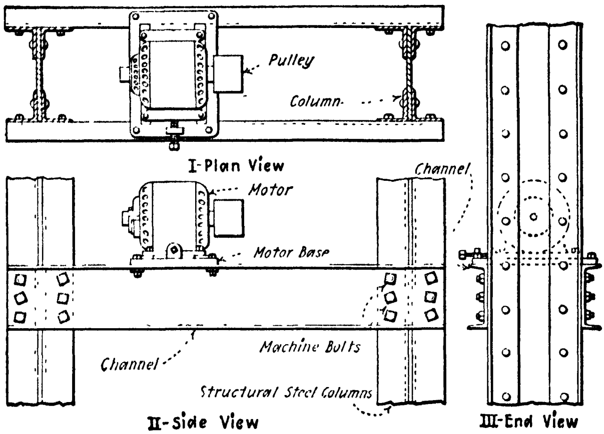


Fig. 54.—Showing method of bridging between structural-steel columns for motor supports.

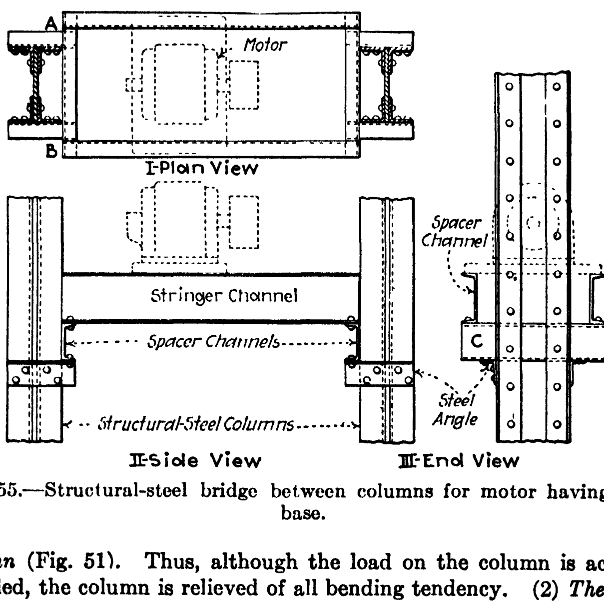


Fig. 55.—Structural-steel bridge between columns for motor having large base.

column (Fig. 51). Thus, although the load on the column is actually doubled, the column is relieved of all bending tendency. (2) *The motor may be placed on beams bridged between two adjacent columns* (Figs. 52,

53, 54, and 55) as described in Sec. 79. (3) *The outer corners of the platform can be supported from the ceiling or by the floor* (Fig. 56). This construction relieves the column of all bending stress and some compressive stress. Those platforms which are partly supported from the ceiling are described under ceiling platforms (Sec. 113).

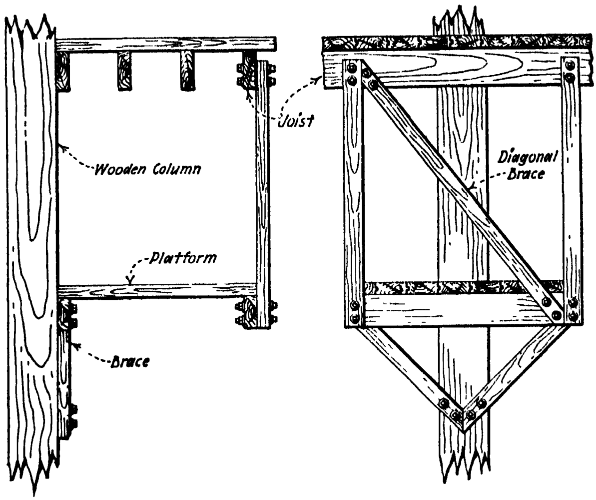


FIG. 56.—Motor platform supported from column and ceiling.

73. A Common And Simple Type Of Column Bracket is shown in Fig. 50. This bracket can be employed only for relatively small motors. It consists of a wooden platform supported on four timbers, two of which are fastened to each of two parallel sides of a wooden post with lagscrews. A punched steel washer should be used under the head of each lagscrew.

74. NOTE.—MATCHED FLOORS ARE PREFERABLE TO PLAIN BOARD FLOORS for all motor platforms. The plain stock, as it dries out and shrinks, leaves open spaces between adjacent boards through which dust, dirt, and probably oil may continually fall to the floor below.

75. Structural-Steel Members Make Very Desirable Motor Brackets For Column Mounting (Figs. 43 and 57).—These brackets are rigid and neat and can usually be made at a low cost especially if several brackets are required. They are

most commonly used on structural-steel columns to which they are fastened with bolts (Fig. 43). When the bracket must be attached to the face of the column instead of to its side, it can be arranged in a manner similar to that shown in Fig. 41. The brackets can also be attached to wooden columns with lagscrews or to reinforced concrete columns with expansion bolts (Fig. 57) or with through-going bolts, if the holes are provided.

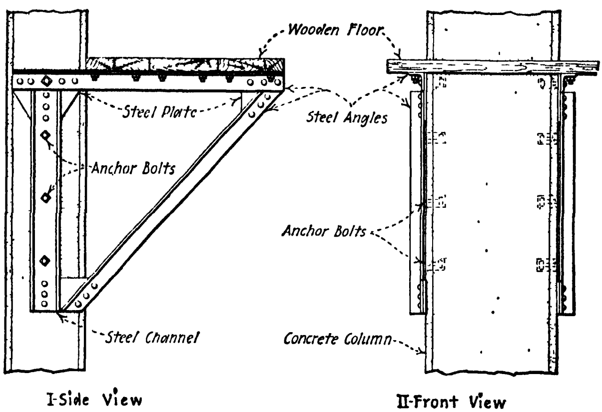


FIG. 57.—Structural-steel motor bracket for mounting on a concrete column.

76. NOTE.—THE CONSTRUCTION OF STEEL BRACKETS VARIES SOMEWHAT.—On small brackets, steel plates may be employed for side braces (Fig. 43) as they make a rigid support and cost little. On larger brackets, angles and channels should be used for the side braces (Fig. 57), because these are more economical than the use of a large steel plate. The steel-plate platform or floor is not usually considered as desirable as the wooden platform; see Sec. 84.

77. The Use Of Stirrups Around Columns To Hold Mounting Boards (Fig. 58) is advisable only for relatively small motors and only where grooves can be cut into the three faces of the column or at least into the back face of it. The grooves prevent the stirrups from sliding down if the tension on the bolts is decreased, due to shrinkage of the wood or to temperature changes. Wood that is well seasoned should be used for the mounting board so that there will be but little shrinkage. This method is employed only for concrete posts,

for in these it is difficult to drill holes. On a wooden column, the mounting board can be fastened directly to the post with lagscrews.

78. NOTE.—A SUPPORT OF THE STIRRUP TYPE is often desirable for mounting the starting devices for motors. For such service, lighter construction may obviously be used than for motor mounting.

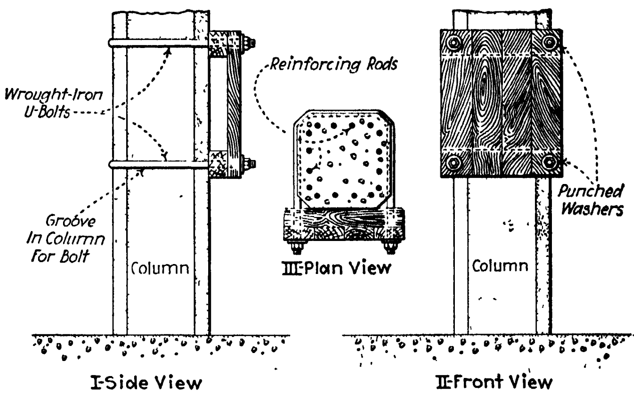


FIG. 58.—Showing method of holding motor mounting board on side of reinforced concrete column.

79. Beams Or Stringers Bridged Between Two Adjacent Columns may frequently be employed for supporting rather large motors, because they do not produce bending stresses in the columns. Such supports can generally be made fairly accessible and also quite rigid. They are particularly desirable where two motors can be placed on one platform (Fig. 52). In buildings composed of wooden members they can be constructed as suggested in Fig. 53. In buildings which have structural-steel columns, steel channels can be employed as stringers (Figs. 54 and 55).

80. NOTE.—THE MOTORS ON STRINGER OR BEAM SUPPORTS SHOULD BE LOCATED as close to the columns as possible so that the support will be as rigid as it can be made with the material employed. When this is done lighter material may be used. The starting device for the motor can be mounted on the nearest column close to the floor.

81. Structural-Steel Stringers For A Motor Support Can Be Arranged On Columns in various manners depending on the

conditions encountered and the materials available (Figs. 54, 55, and 59). An arrangement which is commonly used and which is generally as simple and economical as any is illustrated in Fig. 54. Two channels are bolted directly to the flat sides of the columns and the motor is supported directly on the channels. Several of the ways of attaching the motor to the channels are described in Sec. 86. This type of support is well adapted for motors whose base is about as wide as the

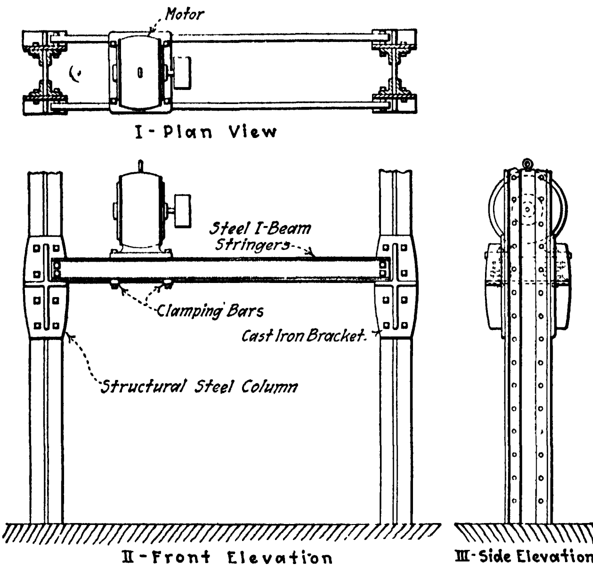


FIG. 59.—A motor support made of I-beam stringers provided with cast-iron brackets.

width of the column. If the motor base is not as wide as the column, two cross channels for attaching the motor base can be bolted between the stringer channels. If the motor base is somewhat wider than the column, the stringer channels may be attached as shown in Fig. 62. When the stringers must be run along the side of the column (for example in the direction *AB*, Fig. 55-*I*) instead of along the face, steel angles can be bolted along the face of the column and the stringers bolted to these in the same manner as the spacer channels, *C*, are bolted in Fig. 55-*III*.

82. NOTE.—CAST-IRON BRACKETS FOR ATTACHING THE STRINGERS TO THE COLUMNS (Fig. 59) are often used, where many identical installations justify the cost of a pattern. They are very desirable where I-beams are employed for stringers, since the latter cannot be readily attached directly to columns. When the stringers consist of channels, it is, if feasible, always desirable to bolt the channels directly to the column faces because this construction, besides saving the cost of the cast-iron brackets makes a stronger and neater arrangement. The channel is to be preferred over the I-beam as a stringer unless extreme rigidity is desired.

83. NOTE.—WHEN LATERAL DEFLECTION OF THE MEMBERS IS LIKELY TO OCCUR (as with a strong horizontal belt pull), they may be reinforced with lattice bars as shown in Fig. 60.

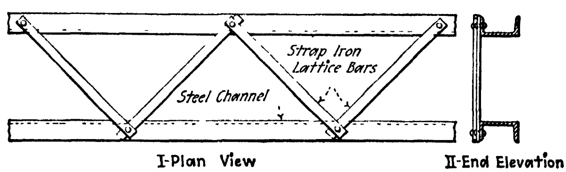


FIG. 60.—Method of reinforcing channel stringers with lattice bars.

84. It Is Desirable To Provide A Floor Around The Motor so that an electrician will have a place to stand when he must work on the motor. Both wooden floors and checkered, steel-plate floors are employed. The only advantage that the steel-plate floor has over the wooden floor is that it is fireproof. It, however, has the disadvantage that a person standing on it is more apt to slip and also to receive a severe shock because it is grounded on the steel frame of the building. Since, in addition to the preceding advantage, the wooden floor is usually more easily obtained, it is generally preferred.

85. NOTE.—ONE METHOD OF FASTENING A WOODEN FLOOR TO STEEL CHANNELS consists of bolting wooden nailing strips to the inside of the channels and nailing the floor boards to these strips. Other methods of fastening the boards directly to the channels may often be devised.

86. The Motor Can Be Fastened To Structural-Steel Stringers in several different ways. A method of attaching the motor, which is simple and probably the most desirable, is illustrated in Fig. 61. Two angles, drilled for the motor

bolts, are clamped under the stringers, and the fastening bolts, passing through the motor base and the angles, hold the machine in place. When the machine is large, small channels are sometimes used as clamping bars (Fig. 62). A clamping

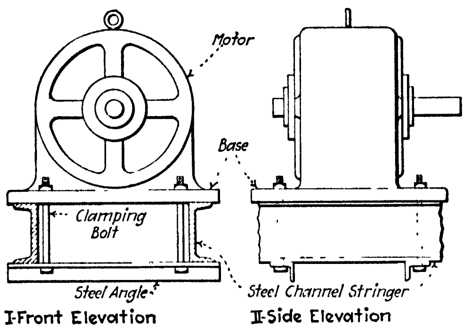


FIG. 61.—Method of fastening a motor to channel stringers with angle clamping bars.

piece, *C* (Fig. 62), which can be a flat-iron forging, a section cut from a channel, or a casting (Fig. 66) should be used to prevent the channel clamping bars from spreading. Another method,

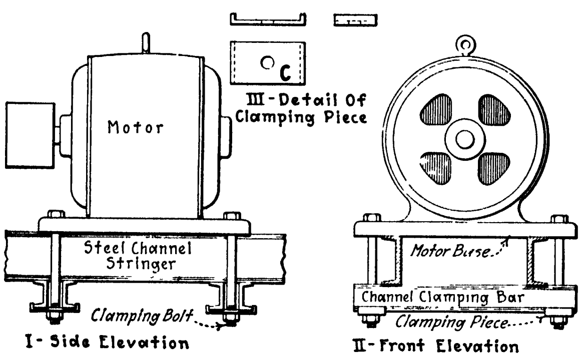


FIG. 62.—Method of attaching a motor to channel stringers with channel clamping bars.

which is commonly employed, is to bolt the motor to the upper flange of the stringer (Fig. 54). Flange or "beveled" washers (Fig. 66) which are beveled to fit the inside of the flange of the

I-beam or channel (Fig. 63) must be used under the nuts of the flathead bolts. These flange washers may be conveniently cast as shown in Fig. 64.

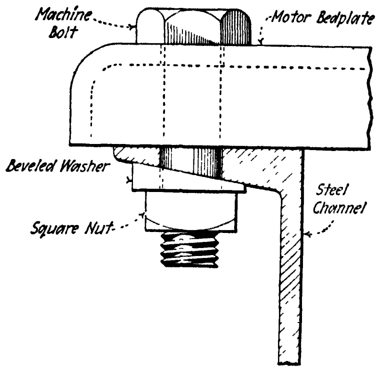


FIG. 63.—Detail showing how beveled washer is used.

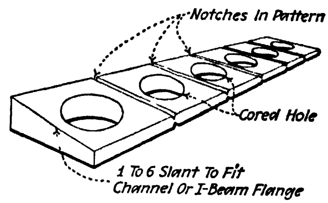


FIG. 64.—Method of casting beveled washers. They may be cast in strips, with notches between washers and broken off as required.

87. NOTE.—A METHOD OF FASTENING THE MOTOR TO STRUCTURAL-STEEL STRINGERS, which is sometimes employed when the width of the

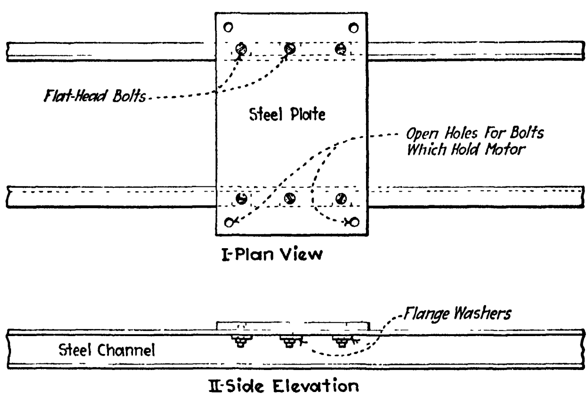


FIG. 65.—A steel plate platform fastened to steel stringers.

motor base is a little greater than the distance between stringers, consists of attaching, to them a steel plate (at least $\frac{1}{4}$ in. thick) to which the motor base is bolted (Fig. 65). The plate is drilled for the motor-base bolts. It is attached to the stringers with flat countersunk bolts, under

the lower heads of which beveled flange washers (Fig. 66) are provided. When the belt pull is vertical, the steel plate should be quite thick to prevent the possibility of its deflection (Sec. 91).

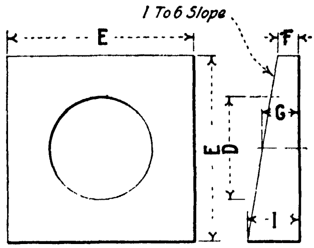


FIG. 66.—Cast-iron beveled washer.

88. Table Of Dimensions Of Cast-Iron Beveled Washers For I-Beams And Channels.—All dimensions are in inches and refer to Fig. 66.

Size of bolt	Diameter of hole	Width, length	Thin edge	Thickness at center	Thick edge	Smallest beam on which it may be used	
	D	E	F	G	H	Channel	I-beam
1/2	9/16	1 1/8	1/8	7/32	5/16	4	6
5/8	11/16	1 1/4	1/8	7/32	5/16	6	7
3/4	13/16	1 1/2	1/8	1/4	3/8	7	9

89. The Method Of Clamping The Motor To The Stringer With Angles Or Channels is generally the most desirable one to use. When this method is employed, the position of the motor on the stringers can be readily changed. The flanges of the channels are not weakened by holes drilled through them. The method is probably also the simplest one, because the holes in the angles can be easily located and then drilled on a drill press. On the other hand, when the motor is bolted through holes in the upper flanges of the channels, these holes must be accurately located and drilled. The latter procedure requires considerably more time and care than the former.

90. NOTE.—THE CLAMPING METHOD IS NOT DESIRABLE WHERE THE BASE IS WIDE and overhangs the stringers on each side, because when the

bolts are placed very far on the outside of the stringers the pull which they exert will tend to spring and perhaps crack the motor base. Under such conditions, the arrangement of either Fig. 55 or 65 should be employed.

91. The Steel-Plate Method Of Attaching The Motor To Stringers (Fig. 65) has been satisfactorily employed where the motor base projects slightly over the stringers. Where the motor shaft is perpendicular to the stringers and the belt pull or gear thrust is not horizontal the steel plate should be quite thick. Under those conditions, the belt pull, since it has a large lever arm, will produce a considerable bending moment in the steel plate. A thin steel plate is not capable of resisting a large bending moment, and hence is apt to vibrate excessively. The pull of the belt, acting at a distance outside of the stringers, will also tend to tilt the motor shaft.

92. NOTE.—THE STEEL-PLATE SUPPORT IS NOT DESIRABLE WHERE THE DISTANCE BETWEEN THE ANCHOR BOLTS IS LESS THAN THE DISTANCE BETWEEN THE STRINGERS (Fig. 67), especially when the belt pull or gear thrust is not horizontal. The vertical component of the belt pull will produce a bending moment in the plate that may cause excessive vibration. A preferable method is to support the motor on cross channels bolted between the stringers (Fig. 68).

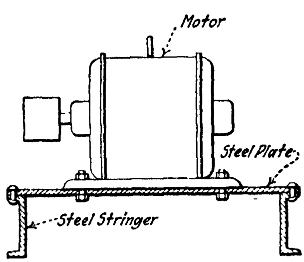


FIG. 67.—A motor base improperly supported on a steel plate.

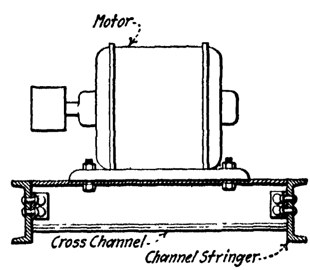


FIG. 68.—A motor, with its shaft perpendicular to the stringers, fastened to two cross channels.

93. The Motor Should Be So Placed On The Stringers that the tendency of the belt pull or gear trust to change the alignment of the shaft will be resisted as much as possible. It is preferable, except when the belt pull is horizontal, to place the motor with its shaft parallel to the stringers. When the motor

shaft must necessarily be perpendicular to the stringers, it is desirable to support the motor on cross members (Fig. 68), which are parallel to its shaft. If it is attached directly to the stringers, the belt pull on the end of the shaft, on account of the narrow base, may tilt the motor and cause it to vibrate. Where the stringers are not held far enough apart by the columns to permit the motor being bolted to cross members, the construction of Fig. 55 may be employed.

94. Note.—When The Belt Pull Or Gear Thrust Is Horizontal, it is desirable to mount the motor with its shaft perpendicular to the stringers. Then, the belt pull will be along, instead of across, the stringers. However, little trouble is experienced when the shaft is parallel to the stringers.

95. In Mounting Motors At Ceilings, no great amount of ingenuity need, as a rule, be used. The principal feature which requires attention is that of security of fastening. Generally speaking, supports which are secured by bolts passing through the ceiling to the floor above are better than others. Lagscrews, expansion bolts, and the like should not be used for ceiling fastenings. Many desirable ceiling supports are shown and described hereinafter.

96. Note.—Ceiling Supports May Be Employed for motors of, say, 25 hp. or less. Such a support saves floor space and does not require the construction of a platform or bracket. However, when a motor is supported on a ceiling it is generally not readily accessible. A motor that has a commutator requires some attention and should, whenever possible, be installed on a platform unless some provision is made for readily getting to it (Sec. 48). Induction motors, since they usually require but little attention, are often supported on ceilings, but even they should, preferably, be located where they are readily accessible.

97. Ceiling Supports For Motors In Buildings Having Wooden Joist Construction may be of the type suggested in Fig. 69. This method of attachment permits the motor to be placed very near to the ceiling and is very easily effected. It presents a neat appearance and is quite satisfactory for motors up to, say, 10 hp. Larger motors and motors which cannot be inverted (see Sec. 66), should be supported on ceiling platforms (Sec. 113).

98. NOTE.—A STRONGER CEILING SUPPORT, THAN THE PRECEDING ONE, FOR A MOTOR, which is to be installed in a building of wooden joist construction, is illustrated in Fig. 70. Iron brackets for the attacrh ment of the motor are bolted to the rafters or beams. Since a suppot-

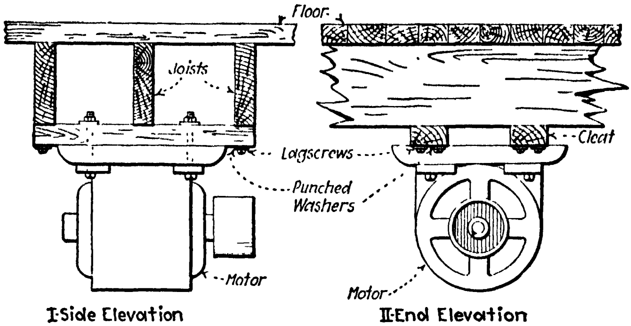


FIG. 69.—Satisfactory method of hanging a small motor from a wooden ceiling.

of this type does not depend on lagscrews but on through-going bolts, it will carry almost any load the rafters will sustain. When the beams are spaced far apart, so that the motor base will not span two or more

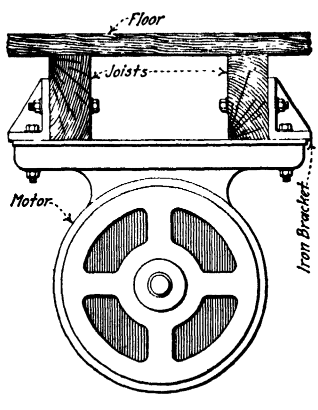


FIG. 70.—Method of attaching a motor to wooden joists with iron brackets.

of them, stringers may be bolted to the beams with the iron brackets and the motor attached to the stringers.

99. Motors May Be Suspended In An Inverted Position From Concrete Ceilings.—As a rule, the motor is fastened to

stringers or cleats (Fig. 71) which are attached to the ceiling or ceiling beams. Either wooden or structural steel stringers may be used but the latter are preferable; see Sec. 103. The method of attaching the stringers to the ceiling varies with

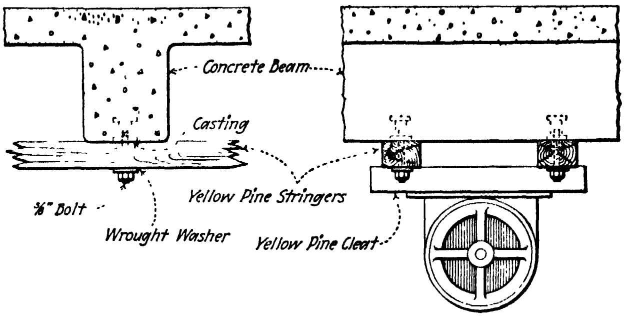


FIG. 71.—Stringers supported from spool-casting inserts set in the concrete beams. Steel stringers would usually be preferable to the wooden ones.

the circumstances under which the motor is installed. If the suspension of the motor is planned before the building is erected, provision may be made for fastening the motor or

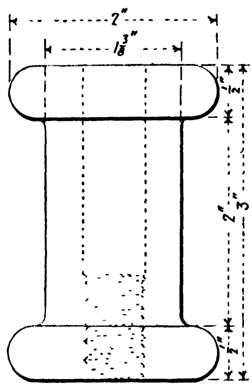


FIG. 72.—Details of a spool casting which can be employed as a threaded insert for supporting machinery.

stringers by casting inserts or box rails (Figs. 72, 73 and 74) in the floor slabs (Fig. 75) or beams at the proper places. When no such provision is made, holes must be drilled in the concrete ceiling or beams for the accommodation of the bolts.

100. Note.—Motors Are Occasionally Fastened Directly To The Ceiling without the use of stringers. Holes are drilled through

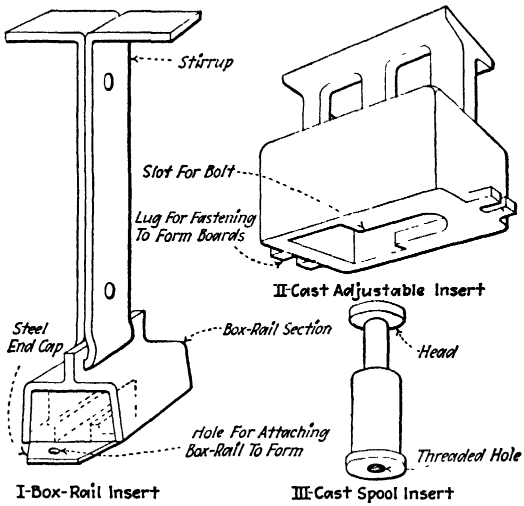


FIG. 73.—Socket inserts for making fastenings to concrete walls, ceilings, etc. (MIDWEST STEEL & SUPPLY CO., New York City). Inserts *I* and *II* provide some adjustment. The cast spool insert, *III*, provides none. It is intended only for supporting light loads.

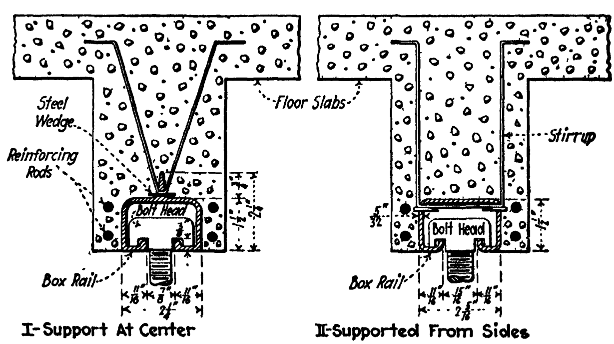


FIG. 74.—Details of box-rail sections and special bolts for use in them. See Fig. 76 for application. (MIDWEST STEEL & SUPPLY CO., New York City.) The bolts are made with rectangular "*T*" heads that can be inserted into the rails from the bottom.

the floor slab and the motor held in place with through-going bolts. Recesses must be made in the upper part of the slab (Fig. 93) for the

bolt heads and the washers, unless their projection above the floor is not undesirable. For small motors, anchor bolts may be inserted in the slab. See also Sec. 126.

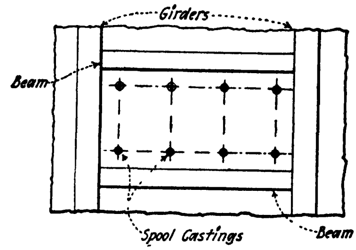


FIG. 75.—Spool-casting inserts cast at regular intervals in a concrete ceiling.

101. Inserts Or Box Rails (Figs. 72, 73 and 74) are often cast in the beams or ceiling of concrete buildings at certain convenient points. Generally, when for supporting stringers, it is desirable to place them in the beams, because then an unbroken line of stringers can be erected and a larger range of

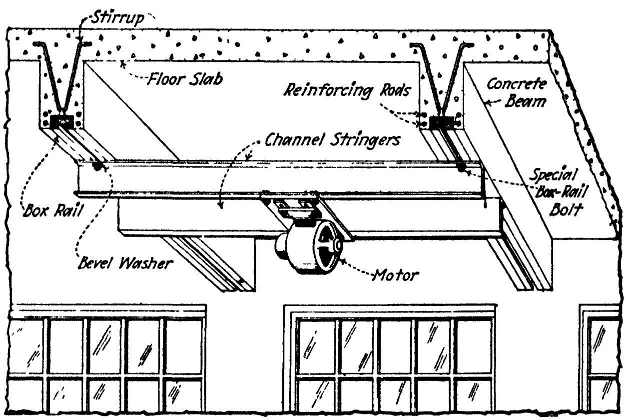


FIG. 76.—Motor supported at ceiling on channel-iron stringers which are fastened to box rails set in the beams.

adjustment can be obtained. Also, inserts capable of supporting a greater load can be installed. The inserts allow for little or no adjustment. The box rails, although more frequently employed for supporting shafting bearings, are very desirable for attaching the stringers (Fig. 76) employed for supporting motors. When box rails are installed, the stringers can be located in almost any position that might be desired.

102. NOTE.—OCCASIONALLY THE SMALL INSERTS (FIGS. 73-*II* AND -*III*) CAN BE SO LOCATED IN THE FLOOR SLAB THAT THE MOTOR CAN BE ATTACHED DIRECTLY TO THE INSERTS with the anchor bolts. Generally, however, since the exact dimensions of the motor and its exact location are seldom known, when the building is erected and, due to the difficulty of accurately locating the inserts, stringers or cleats must be employed also when the inserts are placed in the floor slab. Greater flexibility is obtained when stringers or cleats are employed.

103. Steel Stringers (Fig. 77) are the most desirable because they form a rigid and economical support. Wooden stringers

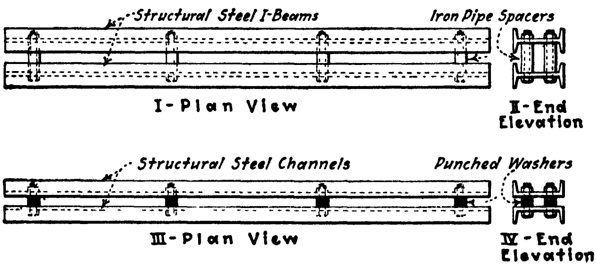


FIG. 77.—Assembled stringers composed of steel channels or I-beams.

often shrink, which results in loose bolts, vibration, and noise. Structural steel stringers are usually of the channel section. Either one channel (Fig. 76) or a pair of channels (Fig. 78) may be employed as a stringer. When a pair of channels (Fig. 77-*II*) is used, no holes need be drilled in the channels where they are attached to the beams or ceiling or where cross-stringer channels are fastened to them. The attachment can be made with through bolts and separator castings (Fig. 91). By using the channels in pairs, the same strength can be obtained with shallower channels and more head room will be available. For a description of the methods of attaching motors to steel channels, see Sec. 87.

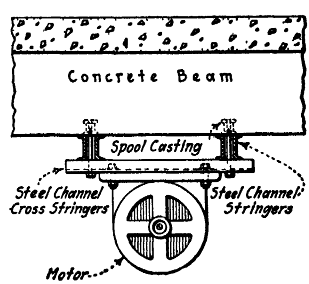


FIG. 78.—Structural steel stringers, consisting of channels used in pairs, supported from steel inserts.

104. NOTE.—SPECIALLY DESIGNED PRESSED STEEL STRINGERS (Fig. 79) and attachment clamps to fit them are made by the Midwest Steel &

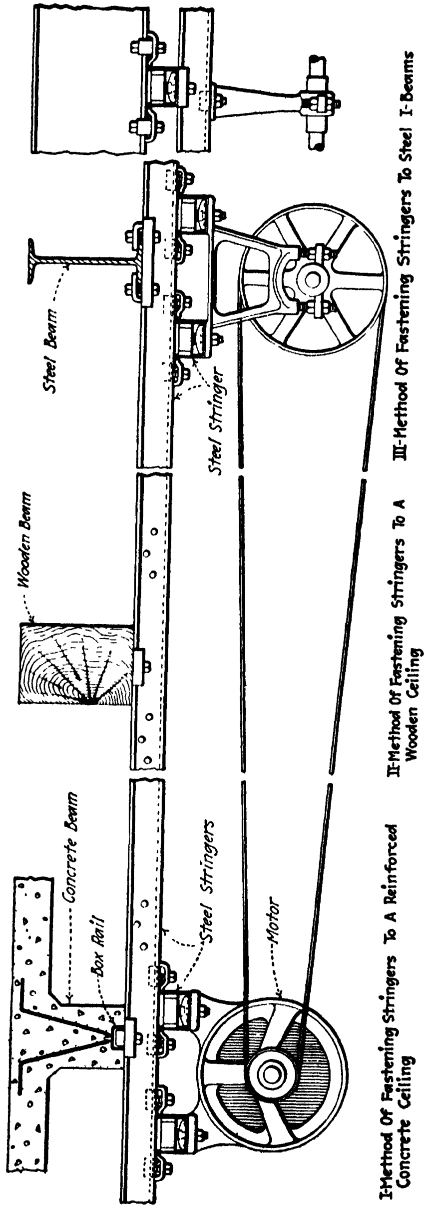


Fig. 79.—Attachment of cross-stringers to longitudinal-stringers when the Midwest Steel Stringer is employed. (Midwest Steel & Supply Co., New York City.)

Supply Co., New York City. These stringers were designed primarily to carry shaft hangers but they may also be used for motor supports.

105. When No Provision Is Made During The Erection Of A Concrete Building For The Hanging Of Motors At The Ceiling, Holes Must Be Drilled in the concrete (Figs. 93, 80, 81, 82, 83, and 84). The holes are drilled usually in the

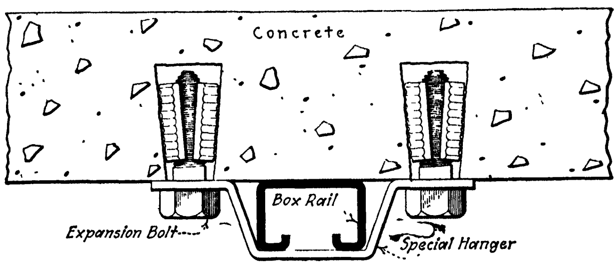


FIG. 80.—Showing method of attaching box rail to existing concrete slab.

beams so as to permit the attachment of the stringers on which the motor is to be supported. Several methods of attaching the stringers to the beams are illustrated in Figs. 81, 82, 83, and 84. The arrangements shown in both Figs. 81 and 82 make strong and neat supports. The method employing the

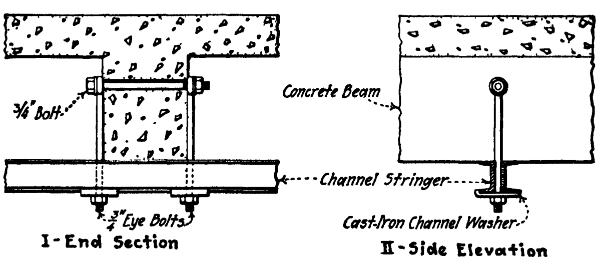


FIG. 81.—Eye bolts hung on horizontal bolts through a concrete beam for supporting stringers to which a motor is to be attached.

eyebolts is probably the stronger although it requires more drilling in the concrete. The holes always should be drilled as close to the neutral axis of the beam as possible so that the beam will not be weakened very much. In the arrangement of Fig. 83, an iron pipe was cast into the beam to form a hole

for the bolt. In the method of Fig. 84, expansion bolts are employed for supporting the stringers.

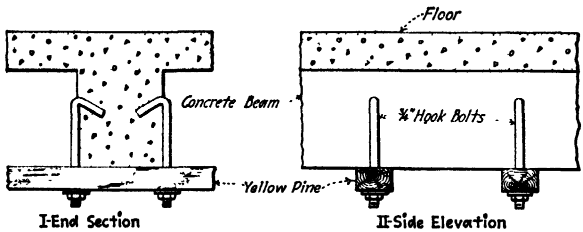


Fig. 82.—Hook bolts placed into concrete beam for supporting stringers.

106. Note.—The Holes Are Drilled Sometimes In The Floor Slab (Fig. 93) and the stringers or cleats held with through-going or expansion bolts. If expansion bolts are used, a number of them should

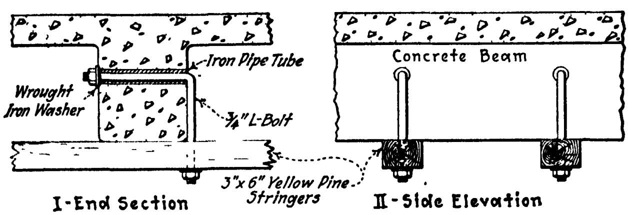


Fig. 83.—Stringers supported from concrete beam with L-bolts.

be employed. With through-going bolts only two need be used for each stringer, provided they are of ample size.

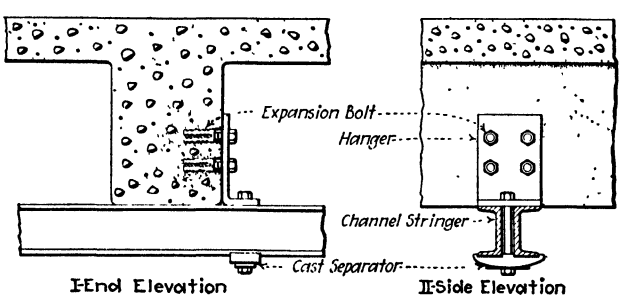


Fig. 84.—A method of fastening double-channel stringer to a concrete beam with expansion bolts.

107. Note.—A Box Rail May Be Attached To A Concrete Beam Or Slab as shown in Fig. 80. The rail is desirable where line shafting is

to be installed but for motor installations in finished buildings the stringers are usually fastened directly to the ceiling or beams. The use of the rails gives greater flexibility.

108. Motors May Be Supported On Or From Overhead Structural-Steel Members such as girders, roof trusses, and the like, when such support seems feasible, provided the members are sufficiently strong to support the motors. See Fig. 85 for a method of holding stringers to I-beams. Steel-channel stringers are preferable to the wooden ones shown. In supporting motors or other equipment from overhead steel members, no holes should be drilled into the members. When there is doubt that certain members can sustain a motor load, a check should always be made as to the advisability of applying the load.

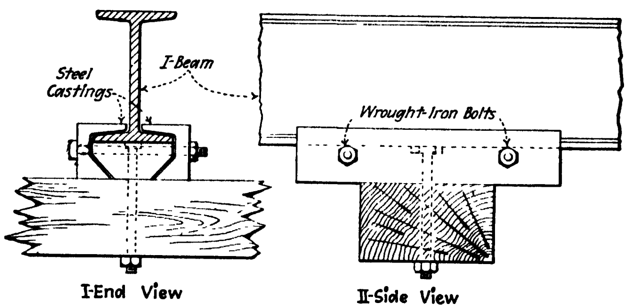


FIG. 85.—Castings for supporting stringers from I-beams.

109. NOTE.—MOTORS SUPPORTED ON ROOF TRUSS MEMBERS (Figs. 86, 87 and 88) are installed upright whenever possible. When the motor is in the upright position, it is more accessible than when it is inverted. The stringers and the motor should be placed on the truss members in accordance with the suggestions given in Sec. 87. The steel plate support (Fig. 65) is not (unless the plate is quite thick) recommended wherever a downward thrust is exerted on the machine and support (Sec. 91).

110. For Connecting Steel-Channel Stringers To Structural Steel Members, Channel Separator Washers Are Useful (Figs. 86, 87, and 91).—The channel washers (Fig. 91) are principally used where a bolt is passed between the backs of two channels. The washers prevent the channels from

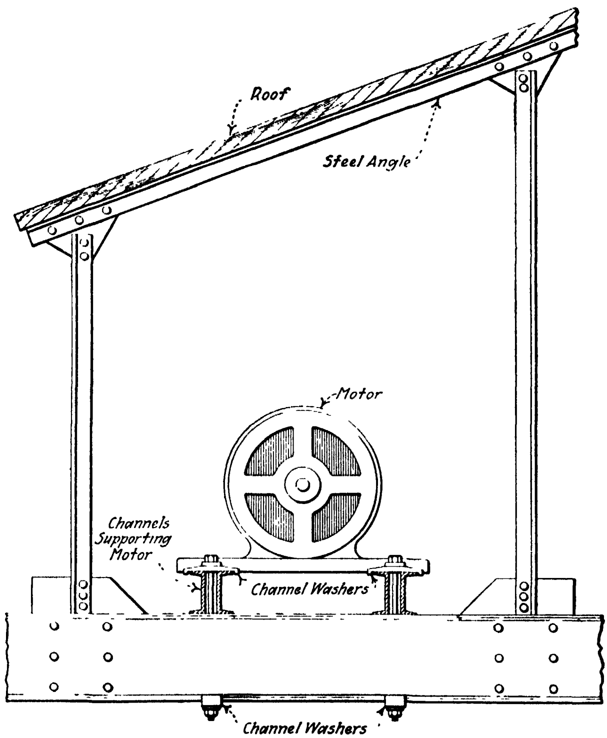


FIG. 86.—Motor mounted on channels clamped to structural-steel roof truss.

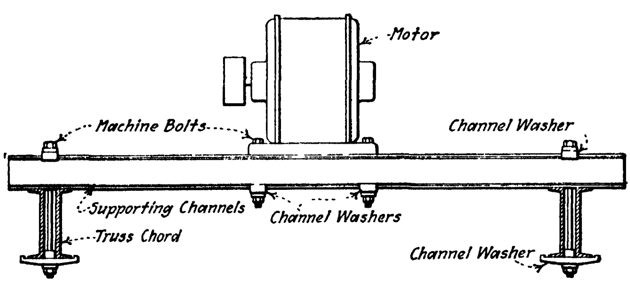


FIG. 87.—Cross section of Fig. 86.

spreading apart and also allow the bolt to be inserted between the channels. When attaching the channel stringers to double-angle members of trusses, the arrangement illustrated

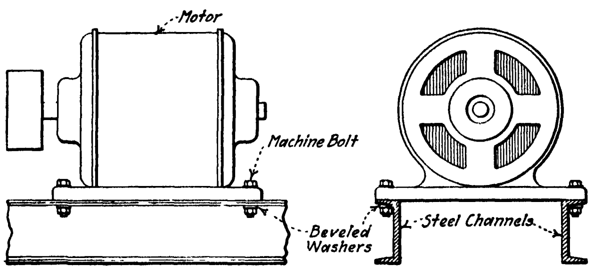


FIG. 88.—Small motor clamped with beveled washers.

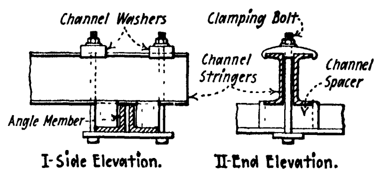


FIG. 89.—Method of attaching channel stringers to a double angle member.

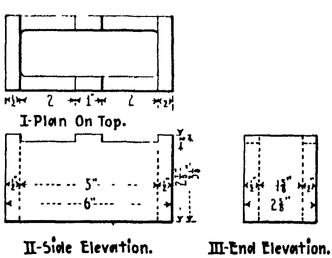


FIG. 90.—Details of cast-iron channel spacer.

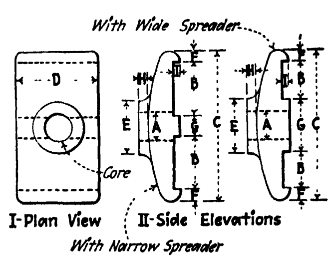


FIG. 91.—Cast-iron channel separator washers.

in Fig. 89 may be employed. Besides two channel-separator washers, two channel spacers (Fig. 90) are used.

111. NOTE.—THE MOTOR MAY BE ATTACHED TO THE STRINGERS by one of the methods described in Sec. 87.

112. Table Of Dimensions Of Cast-Iron Channel-Separator Washers.—All dimensions are in inches and refer to Fig. 91.

Size of channel		Diameter bolt hole	Width of channel slot	Length overall	Width overall					
Depth, inches	Weight, pounds	A	B	C	D	E	F	G	H	I
3 3	4 5	5/8	1 9/16	4 5/8	2	1 1/2	7/16	5/8	1/4	1/4
4 3	5 25 6	7/8 1 1/16 7/8	1 5/8 1 5/8 1 5/8	5 5 1/2 7 1/4	3 2 1/4 3	2 1 3/8 2	1/2 3/8 1/2	3/4 1 1/2 3	1/4 3/16 1/4	1/4 3/16 1/4
4 4 5	6 25 7.25 6 5	5/8	1 3/4	5	2	1 1/2	7/16	5/8	1/4	1/4
5	9	1	2	6	4	2 1/2	1/2	1	1/4	1/4
6	8	7/8	2	8 5/8	4	2 1/4	1/2	3 5/8	1/4	1/4
5	11 5	1 1/8	2 1/16	8	4 1/2	2 3/4	1/2	2 7/8	1/4	1/4
6	10 5	1 1/8	2 1/16	9 1/4	4 1/2	2 3/4	9/16	4	1/4	1/4
7 8 8	14.75 11 25 13 75	1 1/8	2 3/8	8 3/4	4 1/2	2 3/4	9/16	2 7/8	1/4	1/4
8 9 10	18.75 20 15	1 1/4	2 11/16	13 1/2	5	4	5/8	6 7/8	1/8	1/4
10 10	20 15	1 1/4	2 3/4	10 3/4	4 1/2	2 3/4	5/8	4	1/4	1/4

113. Motors Are Often Supported On Platforms Suspended From The Ceiling (Figs. 92, 93, 94, 95, and 96).—With a support of this type the motor does not occupy valuable floor space and at the same time it is fairly accessible. The motor is installed in its normal upright position and, if the distance between the ceiling and the motor is sufficient to accommodate a man, the motor can easily be cleaned and

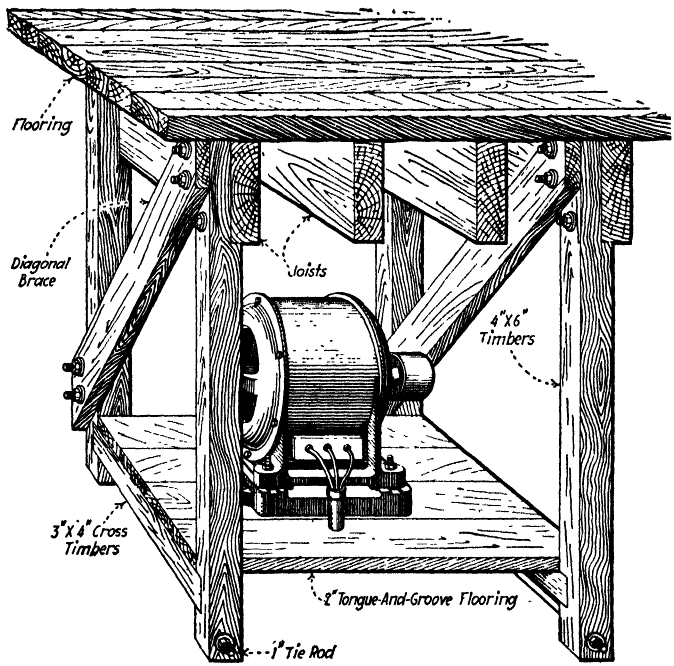


FIG. 92.—Wooden motor platform hung from floor joists.

repaired while in place. For these reasons, the platform support is preferable to suspending the motor in its inverted position from the ceiling. The platforms can be built rigidly and motors of as large a capacity as 40 hp. can be installed in this manner.

114. NOTE.—SEVERAL DIFFERENT METHODS OF CONSTRUCTING MOTOR PLATFORMS are shown in the Figs. 92, 93, 94 and 95. When the platform is installed in a building composed of wooden members, the

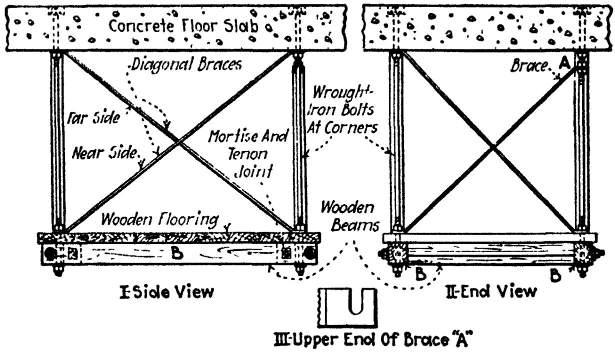


FIG. 93.—Motor platform suspended from concrete ceiling.

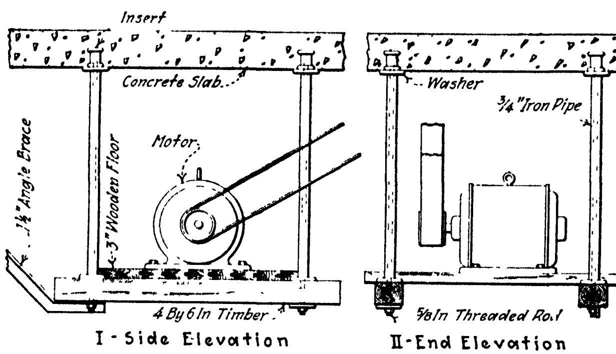


FIG. 94.—Platform suspended by 4 rods and 4 pipes from concrete ceiling provided with inserts. A belted motor as above should have a base or slide rails under it (Sec. 53).

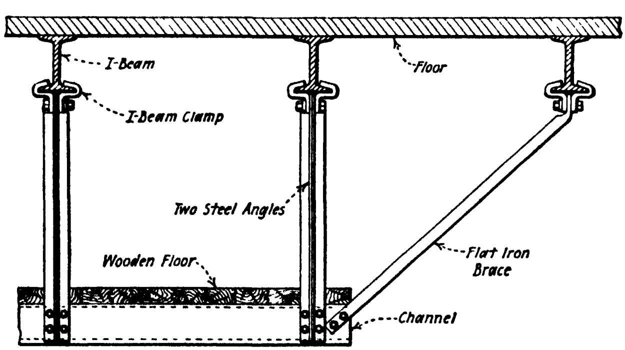


FIG 95.—Platform made of steel angles and channels attached to I-beams.

construction is generally similar to that shown in Figs. 92 and 97. The diagonal brace is employed (when there is a strong belt pull) to insure rigidity. If the joists or beams are not close enough together to permit attaching the platform upright to them, stringers may be fastened to the beams and the platform supported from these. Occasionally, platforms made of structural steel (Fig. 95) are installed in buildings of wooden contruction. In buildings that have concrete ceilings the platform

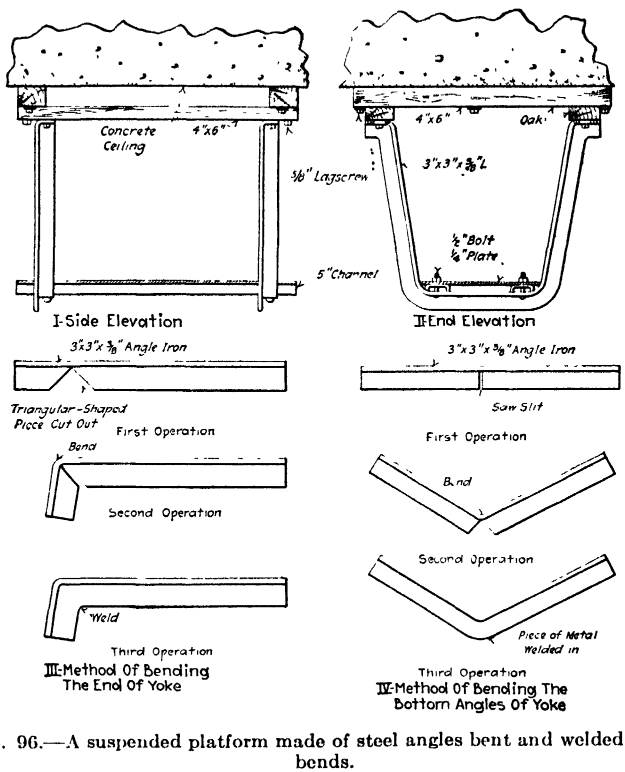


FIG. 96.—A suspended platform made of steel angles bent and welded at the bends.

may be arranged as illustrated in Figs. 93, 94 and 98. The bolts in the arrangement of Fig. 93 serve as both tie and strut members. The nuts on these must be drawn up tight so that the platform will be held rigidly in place. In the arrangement of Fig. 94, the bolts are employed as tie members and the iron pipes as strut members. This platform has been employed with satisfaction for motors of 15 to 20 hp. The brace on the side provides rigidity and is placed so as to resist the belt pull. The brace could be installed between the bottom of one bolt

and the top of another but when it is so placed the platform is not so readily accessible. In steel-frame buildings, the platform may be arranged as in Fig. 95. Steel angles and channels with I-beam hooks are

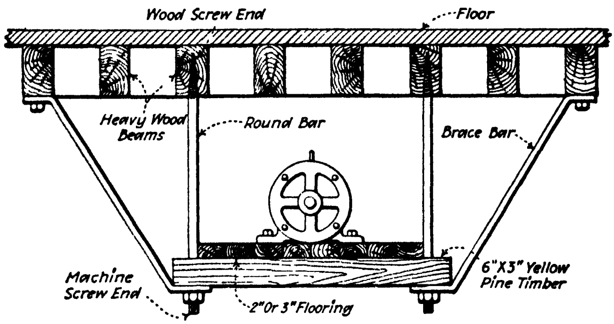


Fig. 97.—Platform for supporting a light-duty motor. (H. S. Rich in *Industrial Engineer.*)

employed. This platform may also be erected in buildings composed of wooden members. The platform of Fig. 96 makes a neat installation where accessibility is not especially required.

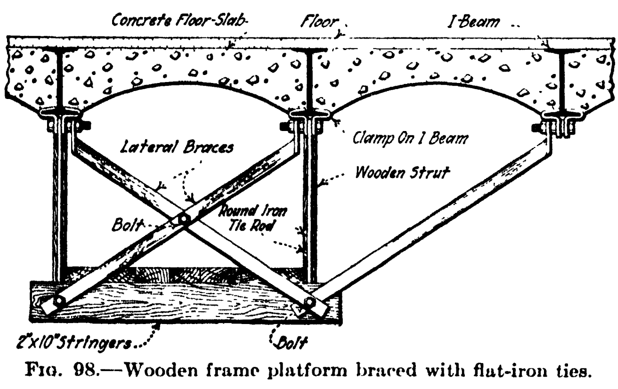


Fig. 98.—Wooden frame platform braced with flat-iron ties.

115. Supports May Be Combinations Of The Floor, Wall, Column, And Ceiling Types as hereinbefore described. One such combination is illustrated in Fig. 45. Here the platform is supported from the wall at one end and from the ceiling at the other end. By this arrangement the wall is practically relieved of bending stresses and still the motor is supported near the wall (Sec. 65).

116. Direct-Connected Or Gear Drive Motors are best mounted so as to be an integral part of the driven machine. Brackets or platform constructed of odd pieces of structural steel shapes make very satisfactory supports for attaching the motor to the machine (Figs. 99, 100, and 101). Such installations are rigid and also readily made with small cost. Steel

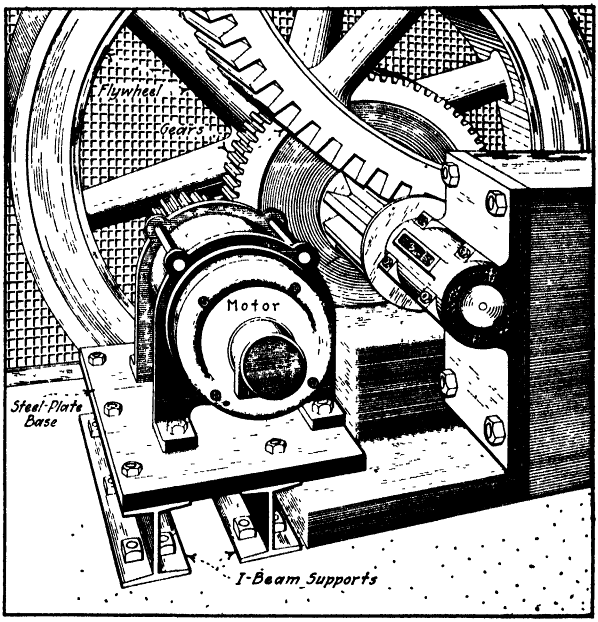


Fig. 99.—A 7.5 hp. motor firmly mounted close to the flywheel of a punch, on a 1-in. steel plate supported on two 5-in. standard H-section members. (A. S. Mill, *Electrical Review and Industrial Engineer*, p. 119, March, 1922.)

members that would otherwise be wasted can be used. With these supports, the machines may be moved without making expensive changes in the motor supports. In Fig. 99, is shown a 7.5-hp. motor mounted on a 1-in. steel plate bolted to two 5-in. H-section members which in turn are bolted to 3-in. I-beams. The I-beams are bolted to a sand-tamped wooden foundation composed of six 12 by 12-in. timbers laid in sets of three, piled crosswise. This gives a good bearing

even for heavy machines. The sand absorbs some of the jar which the punch motor receives.

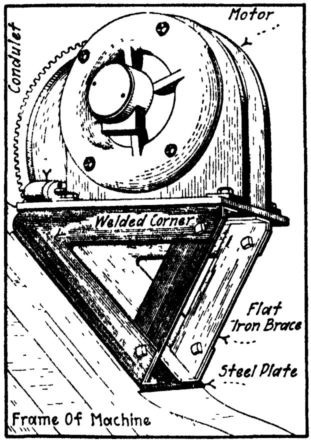


Fig. 100.—A 10 hp. motor mounted on an inclined side of a machine shear. The support consists of two 6 by 6 by 1 in. steel angles bent to allow the motor to rest horizontal as shown and braced at the open end with 3 by 3 by 3/8 in. steel angles. In bending an angle, one leg was cut, and the other then bent as desired. The parts of the cut leg were then welded with an acetylene torch. (A. S. Mill, *Electrical Review and Industrial Engineer*, page 119, March, 1922.)

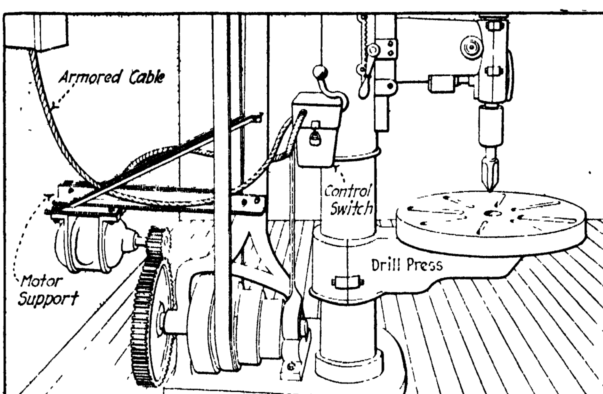


Fig. 101.—A 2-hp. motor suspended from a 15-in. drill by 1½ by 2-in. steel angles. (A. S. Mill, *Electrical Review and Industrial Engineer*, p. 119, March, 1922.)

117. Note.—The Bracket May Be Lead Grouted To The Machine Frame.—This is sometimes done when it is not possible to

attach it to a finished surface. The motor is aligned and the bracket forced into position with wedges. A dam is placed around the feet of the bracket and the space between the bracket feet and the frame filled with lead.

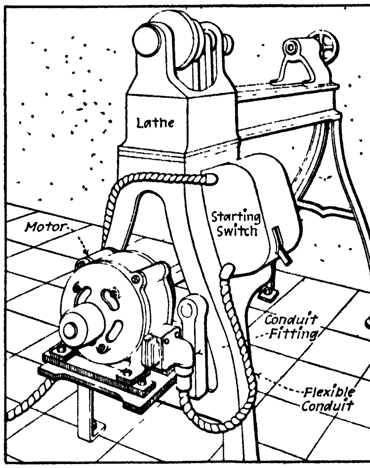


FIG. 102.—Motor attached to lathe. Note compactness of installation and accessibility of starting switch. (J. S. THOMAS, *Elec. World*, p. 595, March 12, 1921.)

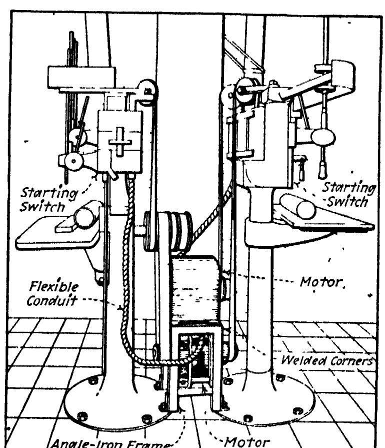


FIG. 103.—One motor mounted above another in the space between two drill presses. (J. S. THOMAS, *Electrical World*, p. 595, March 12, 1921.)

118. Some Satisfactory Methods Of Mounting Small Motors, individual drive, on or near machines, are illustrated

in Figs. 102 and 103. These supports are made of small steel members and are placed in out-of-the-way places as near the driven machine as possible.

119. The Starting Equipment Is Mounted, Usually, In An Accessible Place, as near the motor as possible. Columns or

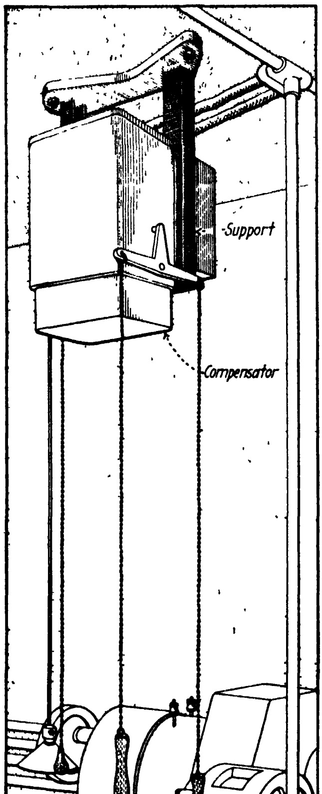


Fig. 104.—A compensator for a 25-hp., 220–440 volt motor mounted on a reinforced concrete ceiling. (H. L. Burns, *Electrical Review aud Industrial Engineer*, p. 245, May, 1922.)

posts close to the motor are convenient places for installing the starting apparatus. Walls also are often employed for this purpose. Where floor space is limited, the starting apparatus can be mounted on the ceiling (Fig. 104). The com-

pensator is bolted to an iron support which in turn is bolted to the ceiling. Three chains are hung from the compensator; two from the starting lever, and one from the tripping mechanism. It has been found that this mounting does not materially increase the time required for periodical examination.

120. Transformers Are Usually Installed Directly On Concrete Floors.—They are sometimes set on a concrete step that is raised 6 or 8 in. above the floor level. In all installations, drainage should be provided to allow any oil which may boil over to flow away quickly. Enough air circulation should be provided around the transformers to keep them from overheating. The large transformers must be installed in a separate transformer vault. See the author's "Wiring For Light And Power" for the construction of transformer vaults.

121. NOTE.—SMALL TRANSFORMERS ARE INSTALLED occasionally on platforms, and often on the building walls. Any of the platforms of the types which have been described for motor supports may be employed for small transformers. When a transformer is installed on a wall, two horizontal cleats are bolted to the wall and the transformer with its hanger (Fig. 204) fastened to these cleats. Such an installation produces a bending moment in the wall and the same precautions should be taken when so installing a transformer as with a motor, Sec. 65.

122. The Holding Strength Of Expansion Bolts is a rather indefinite quantity. The holding power varies so greatly with the type of bolt and with the manner of its installation that definite values cannot be safely given unless these things are known. Various expansion-bolt manufacturers have had many expansion bolts tested to failure in testing machines. Data concerning some of these tests are given in Table 125. From these data the following general conclusions can be drawn: (1) *Under test in concrete,* expansion bolts have been found to sustain about the following average ultimate loads—⅜-in. size, 3,500 lb.; ½-in. size, 5,000 lb.; ⅝-in. size, 6,500 lb.; ¾-in. size, 8,000 lb. (2) *In order to sustain these loads, the bolts had to be in holes of exactly the proper size;* that is, so that the anchors would just enter. (3) *The bolts loosen somewhat after a short time;* under a prolonged loading the bolts may fail

under a load of only about one-sixth of the values given under (1). (4) *In harder material greater loads can be sustained.* Nearly all cases of failure in concrete were by breaking out of the concrete. Tests made in granite and marble show much higher ultimate values. (5) *The holding power of expansion bolts varies considerably with the different makes and types of anchors.*

123. NOTE.—THE HOLDING STRENGTH OF ANCHORS WILL DEPEND ALMOST WHOLLY ON HOW CAREFULLY THEY ARE INSTALLED.—The holes for their reception should be drilled to exactly the proper size. As a rule, the smaller the hole the greater the strength. Follow carefully the

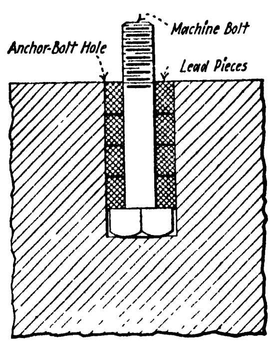


FIG. 105.—An anchor made from lead pipe.

directions given by the manufacturer. Expansion bolts have a greater holding power than most engineers assume.

124. NOTE.—AN ANCHOR MAY BE MADE FROM PIECES OF LEAD PIPE (Figs. 105, 106 and 107). A hole is drilled of such size that the bolt head will just fit in it. The bolt is then placed in the hole and pieces of lead pipe, or strips of lead, of the proper thickness to fill the space around the bolt are placed in the hole surrounding the bolt. The lead is then driven or calked into place with a short length of pipe or some other tool which will fit into the space surrounding the bolt. Enough lead pieces should be used to fill the hole. This anchor is not intended to have as great a holding strength as the commercial anchors.

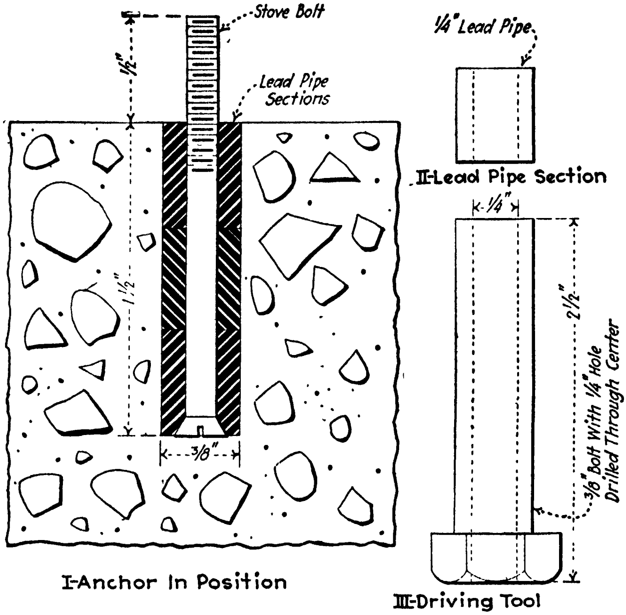


FIG. 106.—Expansion anchor made of sections, *II*, of ¼ in. lead pipe. They are driven in around the bolt with the driving tool *III*.

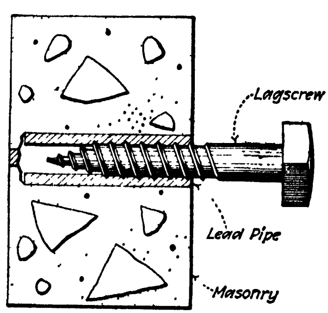


FIG. 107.—Expansion anchor improvised from a piece of lead pipe. This arrangement is much better than a wooden plug which is likely to shrink and become loose.

125. Expansion-Bolt Holding Strength Data (collected). Data not given is not known.

Maker	Trade name	Diameter of bolt, in.	Diameter of shield, in.	Diameter of hole, in.	Length of bolt, in.	Length of shield, in.	Max. load sustained, lb.	Character of failure	Material anchor is set in	Remarks	Source of data	Area of bolt at root of thread	Probable breaking load of bolt on basis of an ultimate strength of 64,000 lb. per sq in.	Per cent expansion bolt strength is of probable plain bolt strength
Isaac Church Expansion Bolt Co., East Norwalk, Conn.	O. K.	5/8	1 1/8	1 1/8	4 1/2	3 1/2	13,880	Bolt broke in thread	Granite	Drive fit	Circular	0.202	12,930	107
	Perfect O. K. (short)	5/8	1 1/16	1 1/16	3 1/2	2 1/2	10,380	Bolt and nut pulled out, shield broke	Granite	Drive fit	Circular	0.202	12,930	80
	Perfect (long)	5/8	1 1/16	1 1/16	4 1/2	3 1/4	14,100	Bolt broke in thread	Granite	Drive fit	Circular	0.202	12,930	109
U. S. Expansion Bolt Co., 139 Franklin St., New York City	Closed back malleable iron expansion shields	3/8	.	47/64	..	2 1/8	4,250	Concrete broke away, case pulled out	Concrete		Letter	0.068	4,350	98
		3/8		25/32		2 1/8	3,950	Concrete cracked; nut pulled out, case remained in hole	Concrete		Letter	0.068	4,350	90
		1/2	.	1 1/64		2 3/4	4,730	Concrete broke away; case pulled out	Concrete		Letter	0.126	8,060	59
		5/8	.	1 5/32		3 1/4	5,000	Wedge nut pulled out of case, no damage to case or concrete	Concrete		Letter	0.202	12,930	39
		5/8	.	1 1/8	.	3 1/4	6,540	Concrete cracked, case pulled out	Concrete		Letter	0.202	12,930	51
		3/4	...	1 3/8	.	3 3/4	7,560	Concrete broke away, case pulled out	Concrete		Letter	0.302	19,320	39

		¾	..	1 7/16	..	3¾	9,010	Concrete broke; case pulled out; end half of case broken off	Concrete	.. ..	Letter	0 302	19,320	47
Savage Expansion Bolt Corp., 11 Desbrasses St., New York City	Pressed Steel Expansion Shields	⅜					4,400	Lagscrew broke	Granite		Letter	0 068	4,350	100
		½	.				6,3–6,500	Lagscrew broke	Granite	. ..	Letter	0 126	8,060	
National Lead Company, 111 Broadway, New York City	Cinch (On two-unit anchors)	⅜		.		.	3,605 3,760	Shear in lead	Concrete, reinforcement 2 in. from surface	.....		0 068	4,350	83 86
							3,440	Shear in lead	Concrete, reinforcement 4 in. from surface	.....		0 068	4,350	79
							3,555	Concrete broke away	Concrete, reinforcement 4 in. from surface	Previously subject to vibration test	Underwriters' Laboratories Tests	0 068	4,350	82
		½					4,465 6,220 7,510 6,125	Concrete failed	Concrete, reinforcement 2 in. from surface	...		0 126	8,060	55 77
									Concrete, reinforcement 4 in. from surface	.		0 126	8,060	93
										Previously subject to vibration test		0 126	8,060	76
		⅝			.		7,460 9,175	Concrete failed	Concrete, reinforcement 2 in. from surface	... ...		0 202	12,930	58 71
							5,880	Concrete failed	Concrete, reinforcement 4 in. from surface	.. ..		0 202	12,930	45
							1,565	Pulled out of concrete	Concrete, reinforcement 4 in. from surface	Previously subject to fire test, ½ hr.		0 202	12,930	12

126. Table Of Recommended Maximum Loads For Expansion Bolts (pounds), when the bolts are properly installed. From the values given in Table 125 the average maximum load that was sustained by each size of anchor for each type or make of anchor (only those set in concrete being considered) was calculated. An average maximum load for each size of anchor was determined by averaging the average loads obtained for the different types of anchors of that size. The test report by the Underwriters' Laboratories on Cinch Anchors showed that these anchors would sustain indefinitely, without appreciable movement, a load of only about one-fifth the ultimate load they sustained. It was assumed, in want of more accurate information, that this ratio would be about the same for all the anchors. Thus, the average loads obtained for each size of bolt were divided by five to secure the load that would be held without movement by each size of anchor. By allowing a factor of safety of 7 for the 3/8-in. anchors, 6 for the 1/2-in. anchors, and 5 for the 5/8- and 3/4-in. anchors, the values of the safe static load given in the table were determined. The safe vibrating load was taken as three-fourth of the safe static load. These recommended values were derived as follows:

Size bolt, in.	3/8	1/2	5/8	3/4
Safe static load, lb	120	200	280	325
Safe vibrating load, lb	90	150	210	245

127. An Anchor For Bolts That Is Guaranteed To Hold Beyond The Tensile And Shearing Strength Of The Bolt is made by the National Lead Company and is shown in Fig. 108. These anchors come in units, each of which consists of two parts: (1) *A conical wedge male part, A*, either plain or threaded, made of malleable iron. (2) *A lead composition female part, B*. Usually, each anchor is composed of two units (as shown in Fig. 108) although as many units as are

necessary for obtaining the required holding power may be employed. Three units, generally, give a holding power equivalent to the bolt strength. The anchors are used in the three ways shown in Fig. 108: (1) *A threaded anchorage reversed and fitted with a machine bolt,* as at *I.* (2) *A two-*

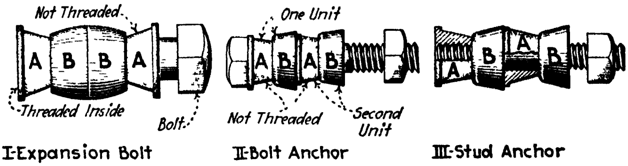


FIG. 108.—Three types of two-unit anchorages before expansion. (CINCH ANCHORS, NATIONAL LEAD CO., New York City.)

unit plain anchorage on a standard machine bolt and nut, as at *II.* (3) *A threaded anchorage fitted on a stud bolt with a nut* as at *III.* See Table 125 for test data on these cinch expansion bolts.

128. NOTE.—THE CINCH ANCHORS ARE INSTALLED ACCORDING TO ONE OF THE FOLLOWING PROCEDURES.—When installing the expan-

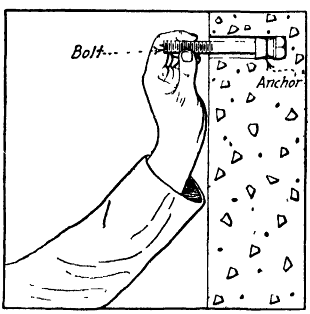


FIG. 109.—Inserting bolt and first unit of anchor shown in Fig. 108 in the hole. (CINCH ANCHORS, NATIONAL LEAD CO., New York City.)

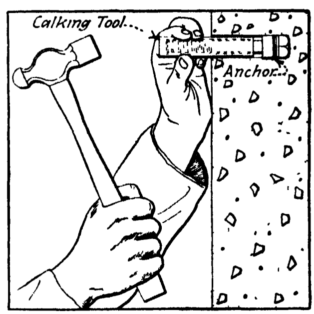


FIG. 110.—Expanding first unit of anchor shown in Fig. 109 in position with a piece of pipe or a special calking tool. (CINCH ANCHORS, NATIONAL LEAD CO., New York City.)

sion bolt anchors (Fig. 108-*I*), the bolt is passed through the work to be fastened and the anchorage assembled properly on the bolt. The work and expansion bolt are lifted into place, the anchor placed in the hole drilled for it, and expansion completed by turning the bolt. The bolt anchor and stud anchor (Fig. 108-*II* and -*III*) are installed by calking (Fig. 109 and 110). The calking method is the most practical and is especially recommended when a heavy object is to be fastened to a side

wall or ceiling since it obviates the necessity of holding the work in position while the bolts are being inserted and the expansion made. The method of installation is as follows: The bolt with the first unit is inserted in the hole as illustrated in Fig. 109. The first unit is expanded in position (Fig. 110) by calking the lead female part with a piece of pipe or a special calking tool. Each of the other units of the anchor are expanded separately in place in the same manner as the first unit. When a stud anchor is installed, the first unit would be threaded and a stud bolt would be employed instead of a standard machine bolt.

129. When Building Machinery Supports, It Is Desirable To Employ The Members As Economically As Possible.—Although it is of prime importance that the support be of sufficient strength to carry the load required, it is also important that the support be not unnecessarily large or costly. In many plants the person who builds the support does not know the strength of the members employed, and to be safe makes them unnecessarily large. Condensed tables of the safe strengths of the more common materials are given in the following sections to give the reader an idea of the loads these materials will carry. More extensive tables can be obtained in the various handbooks. When great rigidity is required, the materials employed must be larger than those which are only sufficiently strong to carry the load. Rigidity, usually, can be best obtained by properly bracing the members.

130. NOTE.—WHEN INSTALLING A MEMBER THAT IS TO BE SUBJECTED TO A BENDING STRESS, it should be so placed and, if feasible, be of such a section that as much of the material as possible is placed at the maximum distance from the center line of a section around which the member tends to bend. For example, see the wooden beams, *B*, which support the platform shown in Fig. 93. There is a bending stress (transverse stress) on each of these beams which tends to bend it around the center line, or *neutral axis*, *AA*, (Fig. 111) of a section perpendicular to the platform floor. For greatest strength the material of the beam should lie as far as is possible from this neutral axis. Therefore, if the timber were installed "flat" (Fig. 111-*II*), it would not be as strong as it would if it were installed "on edge" (Fig. 111-*I*), although the material in the beam would, in each case, be the same.

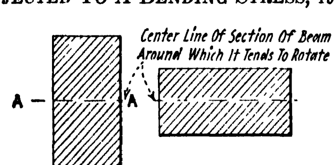


FIG. 111.—Sections through a wooden member employed as a beam. See Fig. 93.

131. The Following Tables Give The Safe Loads That Beams Will Carry subjected to bending stress, when this load is concentrated at the center of the span. A centrally concentrated load imposes the maximum possible stress on a beam. If a beam will safely carry a load which is concentrated at its center, then it will "more than safely" carry that load when

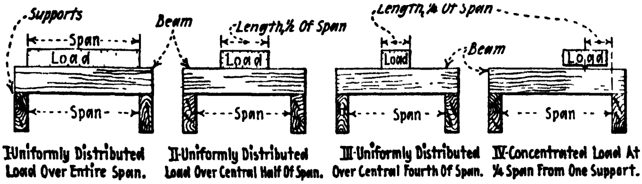


FIG. 112.—Four types of loading arrangements on a beam. These loadings are often approximated but seldom employed exactly at the points shown.

distributed in any manner or concentrated at any point other than its center. The centrally concentrated load is given instead of the uniformly distributed load because, in machine supports, the loading is, generally, more nearly centrally concentrated than uniformly distributed. If the uniformly distributed safe load is desired, (Fig. 112-*I*) it can be obtained

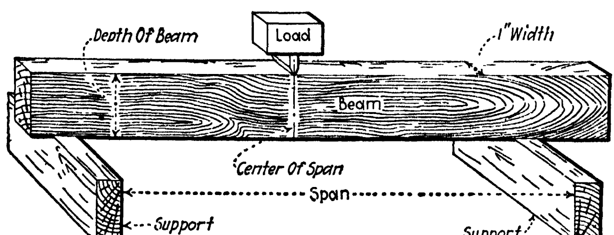


FIG. 113.—Wooden beam centrally loaded.

by multiplying by two the safe load which is given in the table, (Fig. 113). If the load is uniformly distributed over the central half of the beam (Fig. 112-*II*) the load given in the table may be multiplied by 1.33; if over the central fourth of the beam (Fig. 112-*III*), by 1.15; if concentrated at one-fourth the length of the span from one support (Fig. 112-*IV*), by 1.33.

132. Table Of The Safe Centrally Concentrated Loads For Timber, Beams (Fig. 113) of different spans and nominal depths (based on values given in "Handbook Of Building Construction," by HOOL AND JOHNSON). See note below.

Total safe centrally concentrated load, pounds per nominal inch width of beam

Span, ft.	Depth of timber, nominal in.							
	1	2	4	6	8	10	12	14
1	20	100						
2	15	80						
3	...	50	200					
4	.	40	150	370				
5	...	30	120	295	540			
6			100	245	455			
7	.		85	210	390	625		
8	.		. .	185	340	550	805	
9			.	160	305	490	715	980
10			. .	145	270	440	645	885
12	.	. .		.	230	365	535	740
14	.	. .	. .		190	310	460	630
16	.				...	270	400	555
18	. .	.			. .	...	390	490
20	.	.	.	.	...	...	...	440

133. Note.—The Loads Given In The Preceding Table are based on a maximum fiber stress of 1,000 lb. per square inch. This fiber stress is safe and satisfactory for short-leaf yellow pine, spruce, western hemlock, and white oak. To obtain the safe load for beams for woods of other kinds, the following multipliers may be employed: Douglas fir and long-leaf yellow pine, 1.3; white pine, 0.9. As the span increases, the deflection and flexibility of the beams for the loads which are given in the table will also increase. For spans for which the deflection and flexibility would be excessive, no load values are given. Furthermore, when quite rigid structures are required, the longer spans for which values are given, under "Depths of timber," should not be employed unless lighter loads than those tabulated are imposed on them.

134. Example.—It is desired to support a 1,000-lb. motor on a platform by bolting the machine to the platform floor. Two wooden members, each with a 5-ft. span, are to support the floor. If the load is considered centrally concentrated, what size timbers should be used for supporting the floor and motor? Solution.—In the problem given a 1,000-lb. load is held by two timbers, or each timber must hold: 1,000 lb. ÷ 2, or 500 lb. Referring to Table 135, in line with a 5-ft. span, we see that a beam, 2 in. in nominal depth will sustain 30 lb. per nominal

inch width. Hence, a beam of this depth would have to be: 500 ÷ 30 = 17 in. in nominal width. But for economy the beam should have a greater depth than width, so we pass to the next depth, 4 in. Such a beam will hold 120 lb. per nominal in. width. It would have to be: 500 ÷ 120 = 4.17 nominal in. wide. This size might be employed. But assuming a 6-in. depth beam we find it would have to be −500 ÷ 295 = 1.7 = 2 in. wide. This size is the most desirable.

135. Table Of The Total Safe, Centrally Concentrated Load For Steel I-Section Beams, Fig. 114 (based on values given in "Pocket Companion" by CARNEGIE STEEL CO., see Secs. 129 and 130).

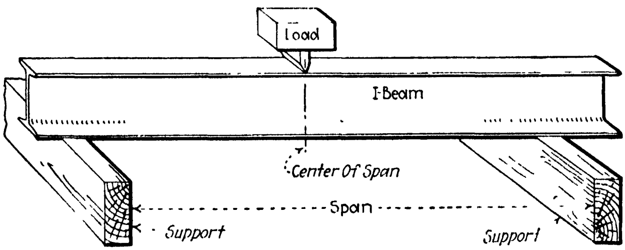


FIG. 114.—An I-beam centrally loaded.

Span, ft	Total safe centrally concentrated load, in 1,000 lb							
	Depth and weight of sections							
	3 in 5 7 lb	4 in 7.7 lb	5 in 10 lb	6 in 12 5 lb	7 in 15 3 lb	8 in. 17.5 lb.	9 in. 21.8 lb.	10 in. 22 4 lb.
1	5.1							
2	4 4	7.6	10 5	13 8				
3	2 9	5.3	8.6	12.9	17.5	....	26.1	
4	2 2	4 0	6.4	9.7	13.8	17.6	25.1	25.2
5	1.7	3 2	5.1	7.7	11.0	15.5	20.1	24 2
6	1.4	2.6	4 3	6.4	9 2	12.9	16.8	20.2
7	...	2.2	3.7	5.5	7.9	11.1	14.4	17.3
8	...	2.0	3 2	4.8	6 9	9 7	12 6	15.1
9	...	...	2.8	4.3	6.1	8.6	11.2	13.4
10	...	...	2.6	3.8	5.5	7.8	10.0	12.1
12	...	...	....	3.2	4 6	6 5	8.4	10.1
14	...	..	....	....	3 9	5.5	7.2	8 6
16	...	...	....	....	....	4 8	6 3	7.5
18	...	...	... .	. .	....	....	5 6	6.7
20	...	...	...	...	...	...	...	6.0

136. Table Of The Total Safe, Centrally Concentrated Load For Steel Channels, load applied parallel to web, Fig. 115

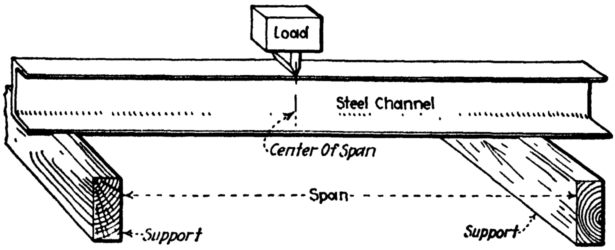


Fig. 115.—A steel channel beam centrally loaded.

(based on values given in "Pocket Companion" by Carnegie Steel Co., see Secs. 129 and 130).

Span, ft.	Total safe centrally concentrated load, in 1,000 lb							
	Depth and weight of sections							
	3 in 4 1 lb	4 in 5 4 lb	5 in 6 7 lb.	6 in. 8 2 lb	7 in 9 8 lb.	8 in 11 5 lb.	9 in 13 4 lb	10 in. 15 3 lb.
1	5 1	7 2	9 5	12 0				
2	2.9	5.0	7 9	11.5	14 7	17.6	20 7	24.0
3	1.9	3 3	5 2	7.7	10.7	14 3	18.7	23.8
4	1.4	2 6	3 9	5 8	8 0	10 7	14.0	17.8
5	1.2	2.0	3 1	4.6	6.4	8.6	11.2	14.2
6	0.9	1.7	2.6	3.8	5 3	7.2	9.3	11 9
7	...	1.4	2 2	3 3	4 6	6 1	8 0	10.2
8	...	1.2	2 0	2.9	4 0	5 4	7.0	8.9
9	..	.	1 7	2.5	3 5	4 8	6 2	7.9
10	.	.	1 6	2.3	3 2	4 3	5 6	7.1
12	.	.		1 9	2 7	3.6	4.6	5 9
14	.	. .	.	..	2 3	3 1	4.0	5 1
16	..	..		.	..	2 7	3 5	4.4
18	.			. .		. .	3 1	3 9
20	..	..	.				..	3.5

137. Note.—The Steel Angles Are Made In Different Thicknesses.—In Table 138, the values for only one thickness for each length of leg are given. If other thicknesses are employed, their strength may be estimated by assuming that the strength increase at the rate of about 0.9 of the increase of thickness Angles with equal legs of other lengths

are made, and their strengths may be estimated by interpolation. Angles with legs of unequal length are also made and they are usually the most desirable when the bending stress acts in one plane. If the long leg is placed in the plane of the bending load, then with the same material, a much larger load (about 34 per cent) can be supported by the angle with unequal legs. For example a 3- by 2-in. angle will sustain about 34 per cent more load than a 2½- by 2½-in. angle of the same thickness.

138. Table Of The Total Safe, Centrally Concentrated Load For Steel Angles, load applied parallel to one leg, Fig. 116

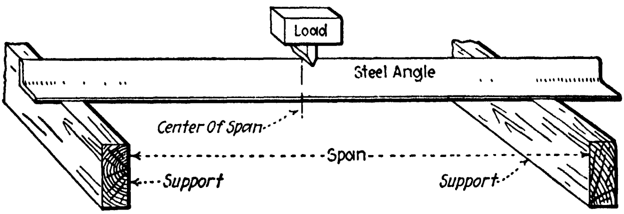


FIG. 116.—A steel angle centrally loaded as a beam.

(based on values given in "Pocket Companion" by CARNEGIE STEEL Co., see Sec. 137).

Span, ft.	Total safe centrally-concentrated load, 1,000 lb.							
	Size of section, in.							
	1 by 1 by 3/16	1½ by 1½ by ¼	2 by 2 by ¼	2½ by 2½ by 5/16	3 by 3 by 3/8	3½ by 3½ by 3/8	4 by 4 by 3/8	6 by 6 by ½
1	0.23	0.69	1.33	2 56	4 42	6.13	8.10	24 58
2	0.11	0.34	0.66	1.28	2.21	3.06	4.05	12.29
3	0.06	0 23	0.44	0.85	1.47	2 04	2.70	8 19
4	..	0.17	0.33	0.64	1.10	1.53	2.02	6.14
5	....	....	0.26	0.51	0.88	1.22	1.62	4.91
6		....	0.21	0.42	0 73	1 02	1.35	4 09
7	. .	..	....	0.36	0 63	0 87	1.15	3.51
8	.	..	...	..	0.55	0.76	1.01	3.07
9			.	.	0.40	0.68	0.90	2.73
10						0 61	0 81	2.45

139. Table Of The Ultimate Holding Strength Of Lag-screws.—The values given are from tests (1) by A. J. Cox,

University of Iowa, 1891, and (2) by Watertown Arsenal, 1884.

Kind of wood	Diameter of lag-screw, in.	Length of lag-screw, in.	Holding power per in. of penetration, lb.	Size of hole drilled, in.
White oak	3/8	4½	1,780 (2)	½
White oak......	9/16	3	2,160 (2)	7/16
White oak..........	½	4½	1,950 (2)	3/8
Yellow pine	5/8	4	950 (2)	½
White cedar (unseasoned)	5/8	4	860 (1)	½
White pine	3/8	2½	1,060 (1)	No hole
White pine	½	4¼	1,270 (1)	No hole
White pine	1	6½	1,580 (1)	No hole
Douglas fir	..	...	(½ values given for white oak.)	

QUESTIONS ON DIVISION 2

1. What are the two requirements an electrical-machine foundation should fulfil? Which usually is the more important?

2. What factors should be considered in choosing a location for an electrical machine?

3. In what manner are generators and large motors usually supported?

4. Should the foundation top be on the same elevation with the floor and why?

5. Give some of the advantages and disadvantages of overhead supports for motors. To what may the motors be fastened when supported overhead?

6. How should the base or slide rails of a belted machine be installed?

7. Describe some desirable ways of providing for anchor bolts in building concrete foundations.

8. Draw a sketch of and explain some methods of supporting machines on wooden or steel beams bolted to the floor.

9. Name the two ways in which motors may be fastened to walls. Give the important advantages and disadvantages of each.

10. Give the precautions that should be taken when mounting a motor with its base toward the wall.

11. Draw a sketch of one method of distributing the load on the wall.

12. Draw a sketch of a wall bracket for mounting a motor. How may the wall be relieved of some of the bending stresses imposed on it?

13. How large should a bracket be made?

14. Draw a sketch of and describe a method of mounting a motor on a column. What precautions should be taken before fastening a motor to a column?

15 Describe briefly the various methods of mounting a motor on a column.

16. Draw a sketch of, and describe, the common method of supporting a motor on stringers bridged between two adjacent columns.

17. What are the advantages of a support of this type?

18. Describe the methods of attaching the stringers to the columns and state when they should be employed.

19. Is it desirable to provide a floor around the motor supported on stringers fastened between columns, and if so what kind is desirable?

20. Describe and illustrate three methods of fastening a motor to structural-steel stringers.

21. Give the advantages of fastening by clamping with angles or channels. When should this method not be used?

22. When may the steel plate method of fastening the motor to the stringers be employed? When is it not desirable?

23. Give the factors to be considered in arranging the motor on the stringers.

24. What is the principal feature which requires attention in mounting motors at ceilings?

25. What are the advantages and disadvantages of supporting a motor on a ceiling?

26. When may a support of this type be employed?

27. Draw a sketch of the ordinary construction for fastening a motor to a wooden joist.

28. Sketch a stronger arrangement than that shown in answer to question 27.

29. How are motors usually fastened to concrete ceilings? On what does the method of fastening chiefly depend?

30. What is the advantage of providing inserts in the ceiling or ceiling beams? When are they usually placed?

31. What material makes the most desirable stringer and why? What sectional shape do you think is generally the best?

32. Sketch and describe several methods of fastening stringers to concrete ceiling beams when no threaded inserts are provided.

33. Describe the usual method of supporting a motor on overhead structural-steel members.

34. Illustrate a good method of connecting steel channel stringers to structural steel members.

35. State the advantages and disadvantages of the ceiling-suspended platform support for motors.

36. Draw three sketches of platforms suspended from ceilings: one suspended from wooden joist; another from steel members; and the third from a concrete slab ceiling.

37. How should direct-connected or geared motors be mounted? Describe an economical way of accomplishing this mounting.

38. Where is the starting equipment usually mounted? How may it be mounted when floor space is valuable?

39. Give four factors which must be considered when the holding power of an expansion bolt is estimated.

40. Can expansion or anchor bolts be made as strong as the bolt employed?

41. When building machinery supports, what factor should be also considered besides the strength of the support?

42. What rule should be followed in placing members that are to be subjected to a bending stress?

43. If the concentrated load (located in the middle of the span), that a beam will carry is given, how may the uniformly distributed load, that the beam will carry, be obtained?

DIVISION 3

ERECTING ELECTRICAL MACHINERY

140. The Methods Employed In The Erecting Of Electrical Machinery depend mainly upon the size and kind of machine which is to be installed and upon the nature of its support. In this division, electrical machines have been divided according to their size and type into the following classes: (1) *Rotational electrical machines, shipped assembled.* (2) *Rotational electrical machines, shipped disassembled.* (3) *Non-rotational electrical machines, shipped assembled.* (4) *Non-rotational electrical machines, shipped disassembled.* The above classes of electrical machines have hereinafter been further subdivided in accordance with the method by which the machines are supported. Such subdivisions are given in the following paragraphs. These classes have been chosen because the methods of erecting all the machines in each designated class are, in general, the same. The methods of erecting machines of each class, which are described separately in the following paragraphs, will apply generally to all machines of that group, but, will not, usually, apply to machines of another group.

141. NOTE.—ELECTRICAL MACHINES ARE, WHEN FEASIBLE, SHIPPED ASSEMBLED.—Only those machines which are so large that they cannot be conveniently handled or shipped when assembled, are shipped disassembled. The larger assembled machines can be installed in sections in the same manner as a disassembled machine, if no facilities for handling the assembled machine are available. It is more economical, as a rule, to install the machine assembled, if this is at all possible, than it is to take it down and erect it in sections.

142. The Moving Of A Machine From Its Place Of Storage to a position near its permanent location is not treated in this division, since such moving of the machine can be accomplished by any of the methods of moving which are described in Div. 1. The method to be employed in any given case will depend on

the size of the machine and the moving equipment that is available, Div. 1.

143. NOTE.—IN THIS DIVISION, THE HANDLING OF A MACHINE FROM A POINT NEAR ITS PERMANENT LOCATION TO THE PLACING AND FASTENING OF IT IN ITS APPROXIMATE POSITION ON THE SUPPORTS WILL BE TREATED.—Thus, for an electrical machine which is shipped completely assembled, only the methods of placing and fastening it in its approximate position on the supports will here be considered. For machines shipped which are disassembled, the assembling of the machines will also be herein described. The leveling of the machine at its exact elevation and the accurate final aligning of the machine, or any of its parts, are treated in Div. 4. Although it is true that in practice, under certain conditions, some parts of a disassembled machine are erected and aligned before other parts are erected, still it has seemed better for the purpose of the book to treat "erection" and "alignment" each in separate divisions. Cross references have been made so that the reader will obtain a knowledge of the proper sequence of the operations. The assembling of the brushes on the machine is also herein treated (Sec. 276). For transformers, the inspecting and filling of the transformer is discussed.

144. Assembled-Rotational Electrical Machines May Be Divided for the purpose of the following discussion, according to the manner in which they are to be supported, into the following four classes: (1) *Those which will be erected on foundations, timber frames, or pedestals.* (2) *Those which will be erected on wall or column supports or on ceiling platforms.* (3) *Those which will be erected on ceilings.* (4) *Those which will be erected on walls.* The methods that are employed in placing a machine on a support of one of the preceding types will be different from those which are employed in placing it on a support of another type. Thus, the erecting of machines on supports of each type will be discussed separately.

145. NOTE.—USUALLY ONLY SMALL MOTORS ARE SUPPORTED ON WALL OR COLUMN SUPPORTS, CEILING PLATFORMS OR CEILINGS — Generators, motor-generator sets, etc., are generally supported on foundations or on floors. The small ones could be installed on brackets and suspended platforms above the floor, but this is seldom done. These generating machines are usually installed in rooms devoted to the generation of power and should be watched carefully by an attendant. It is more important that they be so placed that they can be easily attended to, than it is to save space by placing them on brackets or suspended platforms. Small motors, on the other hand, are installed to run machinery. They are usually mounted close to the machines, in which locations space is valuable. By placing them on brackets or suspended

platforms, considerable floor space is saved. Such an arrangement places the motors out of reach of the workmen, who know little about electrical machinery but who may attempt to fix them; it also renders unnecessary the bringing of belting down to the floor. Motors of capacities larger than 50 hp. are seldom supported on brackets, suspended platforms, or ceilings, but are usually set on foundations or timber frames.

146. Rotational Electrical Machines, Which Are Shipped Completely Assembled, May Be Placed Upon Foundations or pedestals by one of the following several methods: (1) *Lifting by hand.* (2) *Sliding or rolling.* (3) *Lifting with block and tackle, hoist or crane.* The choice of the method will depend upon the size of the machine, the conditions encountered, and the equipment available. Thus, small machines (which can be readily lifted by two or three men) are probably most quickly and economically installed by lifting them onto their supports. However, machines that are to be installed on low foundations are generally slid or rolled onto their supports.

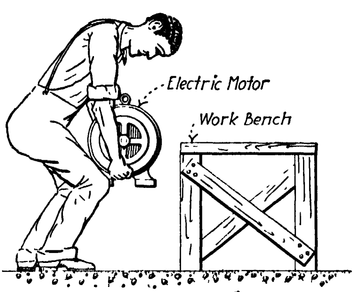


FIG. 117.—Lifting a small electric machine by hand onto a work bench which is used for its support.

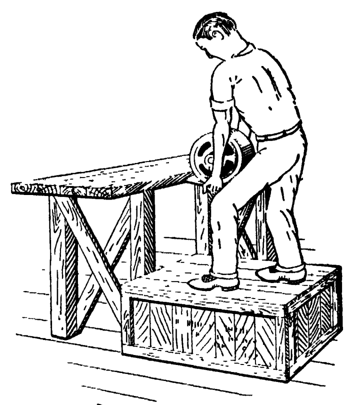


FIG. 118.—Lifting an electrical machine through a large vertical distance by first lifting it into a low box and then onto the permanent foundation.

The hoist or crane method is employed only when the hoist or crane is conveniently located or when the foundation or pedestal is comparatively high.

147. Only Small Rotational Electrical Machines Can Be Lifted Into Position By Hand (Fig. 117).—When a machine can be lifted by two or three men, this method is usually the quickest and most economical. Where the machine is so

heavy that more men are required to lift it, or where the vertical distance through which it must be lifted is rather large, it is desirable to employ one of the other methods.

148. NOTE.—WHEN THE MACHINE CANNOT BE RAISED IN ONE LIFT THE FULL VERTICAL DISTANCE REQUIRED, it may first be lifted onto a box or temporary platform (Fig. 118). From this position it may then be lifted onto its permanent foundation.

149. Machines Can Often Be Slid Or Rolled Onto Their Foundations (Fig. 119).—The customary procedure in so erecting a machine is as follows: The machine, usually bolted to its shipping skids, is moved to a point near the foundation.

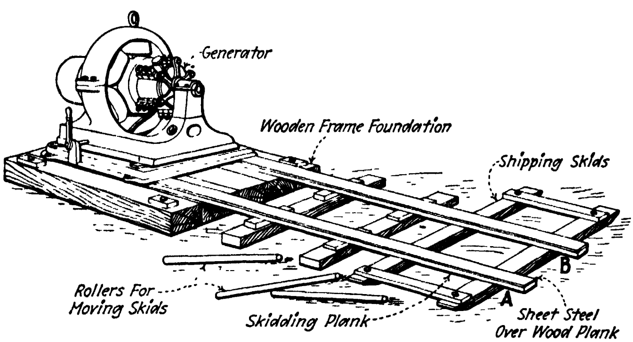


FIG. 119.—Method of sliding a generator from shipping skids onto a low foundation or base.

One side of the machine base is pryed up with a crowbar, and a long heavy plank (*A*, Fig. 119) is inserted beneath it. In the same manner another plank, *B*, is inserted under the other side of the machine base. The planks must be sufficiently long to extend across the machine base, across the space between the machine and foundation, and also across the foundation to a point past the location of far side of the machine base. Enough blocking must be placed under the planks to prevent them from breaking. These blocks should be placed over solid flooring.

150. The Machine Can Then Be Slid Along The Planks By Any Convenient Method (as by pushing, by block and tackle, or by electric truck) to its proper place on the foundation. The movement of the machine along the planks can be facili-

tated by fastening wide strips of sheet steel on the planks and by applying a little oil to these strips. If the angle of inclination of the strips is large, too much oil should not be used; if the oiling is excessive the machine may become uncontrollable and cause trouble.

151. After The Machine Is Properly Located On The Foundation It May Be Left Down Into Position.—This can usually be done with a crowbar by prying up one side slightly to permit the removal of one plank, and then lowering the side onto the foundation. The other side can be lowered in the same manner.

152. NOTE.—WHEN ANCHOR BOLTS PROJECT ABOVE THE FOUNDATION THE MACHINE MUST BE SLID OVER THE TOPS OF THE BOLTS.—This is frequently the case when concrete foundations are employed. To move the machine, enough blocks must be placed between the planks, upon which the machine is slid, and the top of the foundation so that the upper surfaces of the planks are above the anchor-bolt tops. The machine can then be slid to its position above the anchor bolts in the same manner as described in the preceding paragraph. After the machine is in the proper location, that is, when the anchor-bolt holes in the base are directly above the anchor bolts in the foundation, it can be lowered by means of jacks which are provided with lifting toes (Sec. 30).

153. NOTE.—THE METHOD OF ROLLING A MACHINE ONTO A FOUNDATION is similar to the sliding method just described. The only difference being that instead of sliding the machine on the planks, it is rolled thereon on rollers. When rollers are used, less force is required to pull the machine up the planks because the friction that must be overcome is less. The machine must always be held in position, when it is temporarily on the incline, to prevent it from rolling down.

154. When The Foundation Top Is Raised A Considerable Distance Above The Floor, more difficulty is encountered in rolling or sliding the machine into position. Either a long runway with a large amount of cribbing must be constructed (Fig. 120) or the machine must be jacked up onto a high horizontal runway that is well supported (Fig. 20). For the first method, considerable space and timber are required. For the second, jacks are required. Of the two methods the latter is probably the best and the one most commonly employed. However, both methods are slow. They should, if possible, be avoided. The machines should preferably be lifted onto the foundation whenever the necessary lifting equipment is

available. When heavy machines are to be moved and no crane is available, one of the above methods may be desirable, usually the latter.

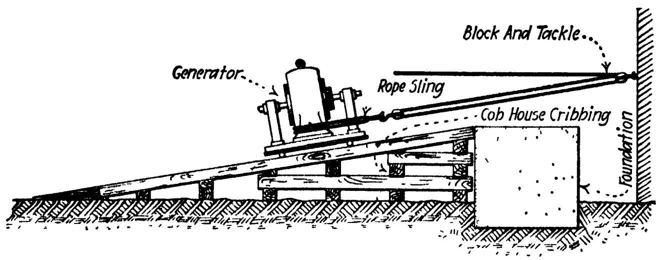


FIG. 120.—Rolling an electrical machine onto a high foundation by cribbing up a runway.

155. NOTE.—WHEN A LONG INCLINE IS EMPLOYED for rolling a machine on a foundation, care must be taken in building the runway. The slope of the incline should not be greater than one in six. A smaller slope is preferable and should be employed if the space is available. A considerable force is required to start a machine up a steel slope and, as a rule, one in six is the maximum slope which should be used with ordinary tools and rigging. Different methods of supporting the incline may be employed. Cob-house blocking (Fig. 120) is easily built and is often used, but it requires more material than any other method of supporting. For a long, high run it is better to do a little framing as shown in Figs. 121 and 122. Such construction requires much less timber and at the same time is very strong. The diagonal braces shown in Figs. 121 and

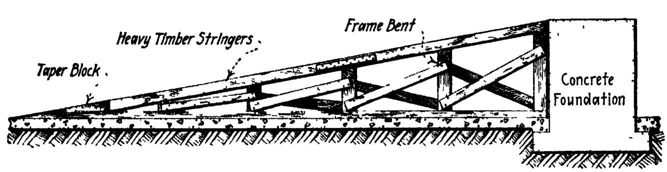


FIG. 121.—Supporting an inclined runway by means of framework.

122 are necessary to stiffen the frame and to enable it to resist twisting. In pulling a machine up the incline, the force should be applied parallel to the incline; that is, the ropes of the block and tackle should be parallel to the incline. By pulling in this manner less force is required, and also less strain is imposed on the runway, than when the pull is horizontal.

156. NOTE.—A MACHINE MAY BE JACKED UP ONTO A CRIBBING by a procedure which is the reverse of letting it down (Sec. 29). Thus, by means of four jacks, which are provided with lifting toes, the machine is raised as high as the jacks will permit. Cribbing (Fig. 20) is then built

up under the machine and the jacks lowered until the machine rests on the cribbing. The timbers, *A* (Fig. 20), are then placed at a high elevation in the crib. By resting the jacks on these timbers, the machine is again jacked up as far as possible. The cribbing is then continued higher and the machine lowered onto it. This process is repeated until the cribbing is as high as the foundation. Then rollers may be inserted under the machine so that it may be rolled onto the foundation.

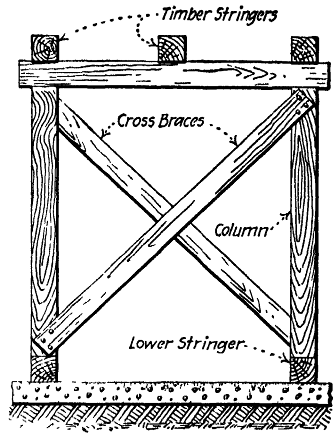


FIG. 122.—Frame bent employed in framework supporting runway shown in Fig. 121.

157. The Methods Of Sliding Or Rolling Machines Onto Their Foundations are very commonly employed. The method of sliding is very satisfactory for placing small machines on low foundations—say those which are less than 6 or 8 in. high. The method of rolling is particularly well adapted for erecting medium-sized, assembled machines upon low foundations which are up to about 1½ ft. in height. In the average installation of this type, cranes or hoists are usually not available. Where the foundation is low and where a crane or hoist is not at hand, generally less time is required to slide or roll the machine into position than would be necessary for lifting it on with a block and tackle fastened to some upper member. But when the top of the machine support is a considerable distance above the floor, then lifting the machine onto its support is more desirable than sliding or rolling it. The method of sliding or rolling machines in such cases requires either a long runway or the jacking up of the machines, both of which are undesirable (Sec. 146). When no crane is available, large assembled electrical machines must be rolled onto their foundations, even though the foundations are high, because these machines cannot be raised with block and tackle.

158. Electrical Machines Can Be Lifted Upon Their Foundations in various ways. Any lifting device which is available, may be employed provided it is strong enough to

carry the load. For raising small- and medium-sized electrical machines, which are assembled, a block and tackle or a chain block is most frequently employed. The larger and heavier—assembled machines usually require cranes or pneumatic hoists to raise them. The methods of lifting machines onto foundations are described in the following paragraphs.

159. NOTE.—A CHAIN BLOCK IS MORE DESIRABLE for lifting motors than a rope tackle and blocks. The chain block, usually, has a larger ratio between the force required to lift the load and the load itself than has the block and tackle. A chain block is, however, generally limited to short lifts. The trouble given by chain slings (Sec. 10), of links breaking without warning, is not experienced with chain hoists because chains on these do not twist and kink.

160. A Block And Tackle Or A Chain Block (Fig. 123) may be employed to raise small- or medium-sized electrical machines onto their foundations. The machine should be placed beside its foundation and about 4 to 6 in. away from it. Two 2- by 4-in. timber blocks, *A* (Fig. 123), preferably tapered, should be fastened between the machine and its foundation. These blocks prevent the machine from rubbing on the foundation side. When the foundation is low—say 1 to 3 ft. in height—and narrow, it is desirable to fasten the block to some upper member which is directly over the machine's position on the foundation. If the block is thus fastened, the machine, after it has been raised above the foundation, can then be lowered into its proper position on the foundation. This procedure is particularly desirable when anchor bolts project above the foundation top (Fig. 123); the machine can be let down with its bolt holes directly over the tops of the anchor bolts.

161. NOTE.—IF ANCHOR BOLTS PROJECT ABOVE THE FOUNDATION TOP, WOODEN BLOCKS *B*, SHOULD BE PLACED (Fig. 123) ahead of the bolts to prevent the machine, as it is being raised, from rubbing on the bolts. These blocks also protect the bolts from being bent. Also, they allow the machine to swing clear of the foundation top and the other anchor bolts (Fig. 124), after it has been raised above the blocks. The blocks should be about 1 in. higher than the anchor bolts.

162. NOTE.—SOME PRECAUTIONS TO BE TAKEN WHEN USING THE ABOVE METHOD ARE: Some machines have lugs on their baseplates for holding the adjusting screws (Fig. 123). Care should be taken in

handling these machines not to strain the lugs too much, since they are easily broken. An eyebolt will not withstand very much side strain. Before pulling the machine up the side of the foundation, the eyebolts (both the one supporting the tackle and the one on the machine) should be examined to determine whether they will withstand the strain that is to be imposed upon them. If not, the methods described in Secs. 21 and 22 may be employed.

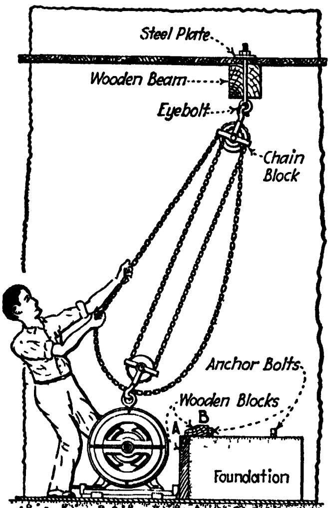


FIG. 123.—Method of lifting a motor with a chain block onto a foundation which has anchor bolts projecting above its top. (First step.) Note the base-adjusting screws on the right-hand side of the motor have been removed because they might give trouble in scraping on the side of the foundation.

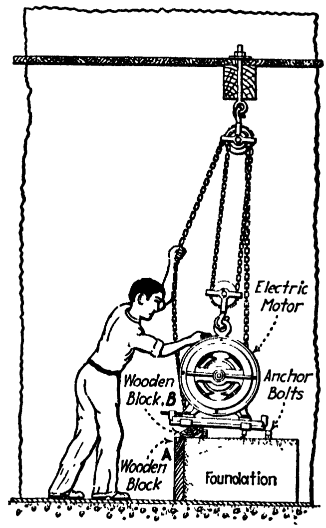


FIG. 124.—Method of lifting a motor with a chain block onto a foundation which has anchor bolts projecting above its top. Block, *B* prevents motor base from sliding into fartherest anchor bolt. (Second step.)

163. NOTE.—IT IS NOT SAFE TO LIFT MACHINES OF ALL TYPES BY THEIR EYEBOLTS.—The small motors and generators may be lifted by the eyebolt which is provided on the top of the frame. Large machines cannot be safely lifted in this manner, because on these machines the eyebolt is designed to carry only the weight of the stator or frame.

164. When The Foundation Is High Or Wide, It May Be Desirable To Fasten The Tackle Or Chain Block, Over The Edge Of The Foundation.—Then the machine, after it has been raised above the foundation, can be swung over a

little and lowered onto rollers which have been placed on the foundation top (Fig. 126). It can then be rolled to its permanent position and let down from the rollers with crowbars. When this method is employed, less force is required to raise the machine than with the method described in Sec. 161 because the direction of pulling is more nearly vertical. Consequently less side strain is imposed on the eyebolt. But with this method, the machine must be rolled into place and then let

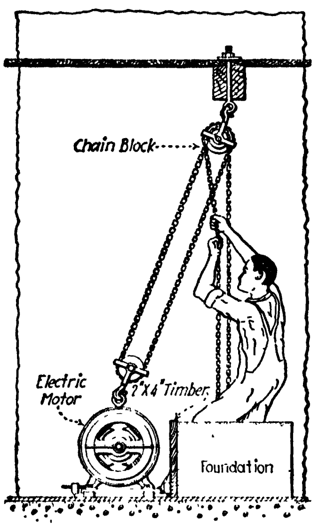


Fig. 125.—Method of lifting a motor with a chain block onto a foundation which has no bolts projecting above its top. (First step.)

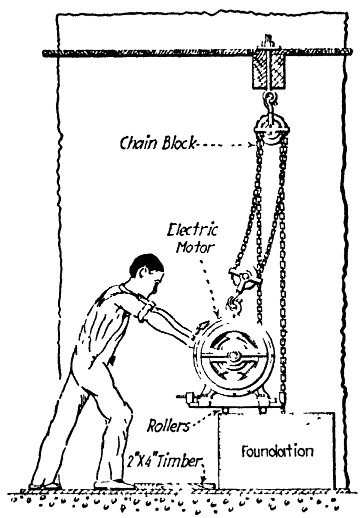


Fig. 126.—Method of lifting a motor with a chain block and tackle onto a foundation which has no bolts projecting above its top. (Second step.)

down from the rollers with the crowbars. The method of Fig. 125 is less desirable than that of Fig. 123. This is especially true where anchor bolts project above the foundation top unless the foundation is high or wide and the angle between the line of pull and the vertical is large, or unless the machine heavy.

165. Note.—The Method Just Described Can Also Be Employed Where Anchor Bolts Project Above The Foundation.—This may be accomplished by placing the blocks *B* (Fig. 124) in front of the anchor bolts and then raising the machine a sufficient distance above the blocks

so that the rollers (supported on cross timbers of the same thickness as block *B*) can be inserted under the machine. The machine can be let down onto these rollers and rolled into position as previously described. The method discussed in Sec. 160 is generally the more desirable; it requires less time, unless the foundation is high or wide. When the foundation is high or wide, the angle between the vertical and the line of pull becomes large; the force required to raise the machine is greatly increased by the side friction and the side pull of the tackle or chain block.

166. Another Method Of Lifting A Machine With A Block And Tackle Or Chain Block Onto A High Or Wide Foundation

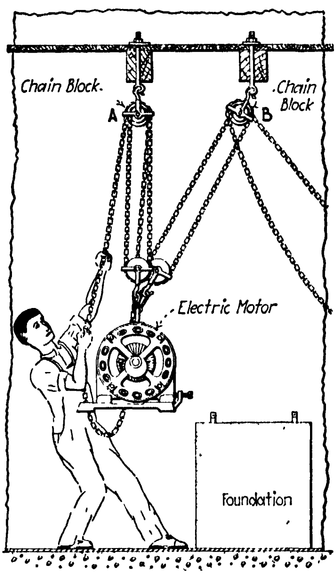


Fig. 127.—Method of placing a machine on a foundation with two chain blocks. All the load is carried by tackle *A*. (See also Fig. 126.)

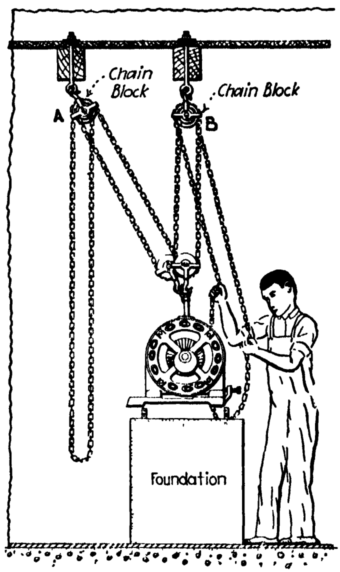


Fig. 128.—Method of placing a machine on a foundation with two chain blocks. All the load is carried by tackle *B*. (See also Fig. 127.)

(Figs. 127 and 128), is first to raise the machine vertically to an elevation higher than the foundation top and then swing it over the foundation into the proper position. This method is very satisfactory for lifting medium-sized machines, including motor-generator sets, onto high foundation, especially where anchor bolts project above the foundation. It, however, requires two blocks and two supports for them. These are not always obtainable.

167. Explanation.—The procedure is simple: The machine is lifted by the block *A* (Fig. 127), to an elevation higher than the foundation. The block, *B* (Fig. 127), which is supported directly over the machine's permanent position, is then fastened to the machine. The load is transferred gradually from block *A* to block *B*, until the machine is carried wholly by block *B* (Fig. 128). The machine is then let down into its position on the foundation. This method requires more time than that described in Sec. 160 but less time than that described in Sec. 164.

168. Note.—When Two Blocks Are Not Obtainable (Fig. 127), the machine can be raised vertically by one block to a height above the foundation. A platform or a crib of the same height as the foundation may then be placed or built under the machine. By inserting rollers underneath the machine, it can be rolled onto the foundation. This method is not recommended, however, since it requires more time than any of the others. It should be employed only when the other methods described cannot be used or when a platform of the proper height is readily available. Under the latter conditions it is more desirable than the method described in Sec. 164. By this "platform" method, heavier machines can be raised than by any of the other methods previously described.

169. A Gallows Frame May Be Employed (Fig. 129) for supporting the chain block or the rope tackle. Such a frame is desirable where ready means cannot be found for suspending the chain block or rope tackle at the proper points. It will also save considerable time where many motors are to be lifted. When it is used, no bolts or other means for suspending the block need be installed in the ceiling above each motor installation. When a gallows frame is employed, the electrical machine can be lifted up vertically alongside the foundation to such a height that it will clear the foundation. The frame can be rolled into a position so that its cross piece will span the foundation Then the electrical machine can be let down onto its foundation into the desired position.

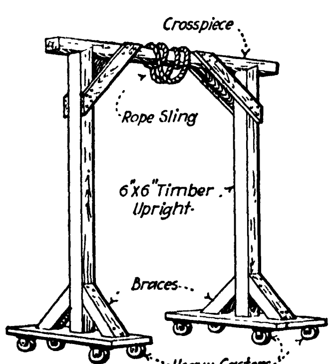


Fig. 129.—A gallows frame for supporting a chain block or a block and tackle.

170. NOTE.—IT IS USUALLY PREFERABLE TO FASTEN HEAVY CASTERS ONTO THE BOTTOM OF THE GALLOWS rather than to use pipe rollers under it. When casters are employed, the gallows can be rolled about easily even for long distances. When moving a gallows on pipe rollers, rollers must always be inserted ahead of the rollers already under the gallows. This procedure retards the moving process. Casters can be obtained which have a carrying capacity of 5,000 lb.

171. Chain Blocks Or Hoists May Be Suspended In Buildings Consisting Of Wooden Members by one of several methods. When the place for installing the chain block falls directly under a wooden beam, a screw eyebolt or a screw hook can be turned into the underside of the beam. The chain block can then be suspended from it. This is one of the simplest methods of suspending a chain block and, although unreliable, is commonly employed. The size of the screw eyebolt that should be used will depend evidently upon the weight of the machine to be lifted. When there is no beam above the place where the chain block is to be installed, the screw eyebolt may, sometimes, in an emergency, be screwed directly into the wooden floor, provided the floor is strong enough to carry the load and sufficiently thick to accommodate the screw. The preferable and safe method is illustrated in Fig. 130. In this method, a hole is bored entirely through the floor or beam above. If necessary, a cross-support (*S*, Fig. 130) which has a hole bored through it, is placed above the hole across the upper floor. This is to distribute the load over a large floor area. This support should, preferably, span at least two joists. The nut eyebolt is then passed through the floor and cross support; a washer and nut are attached.

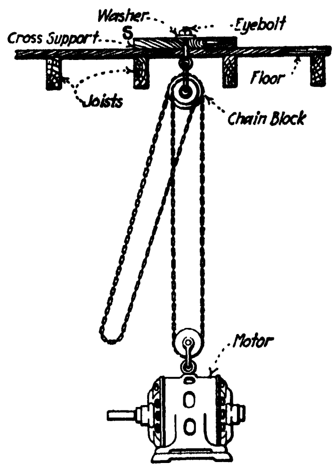


FIG. 130.—Supporting a chain block from a timber laid across the floor above.

172. NOTE.—ANOTHER METHOD OF SUPPORTING A CHAIN BLOCK OR HOIST FROM A WOODEN BEAM IS BY means of a hook grip (Fig. 131). These hooks can be made out of 1½- by ½-in. flat iron, forged flat to a

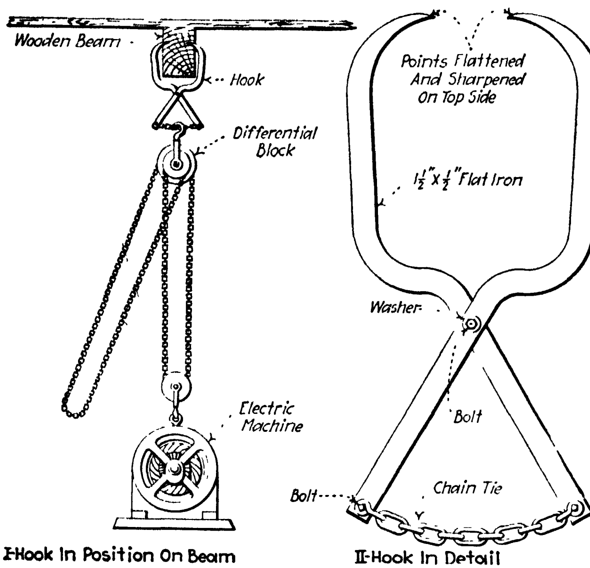


FIG. 131.—A hook grip for attaching a chain block to a wooden beam. This hook can be employed for only relatively light loads.

width of ¾ in. at the points. The tops of the knife-blade points should be ground sharp. The under sides of the points should not be ground; this would tend to permit the hook to slip. The lower ends of the hooks should be connected by a short chain secured by bolts. A convenient length for the hook is 18 in. When the hook is slipped over a beam (Fig. 131-*I*), and a pull is exerted on the chain, the sharp points are forced into the wood and prevent the hook from slipping. The principle is similar to that of the ice tong. These hooks may be economical where many machines have to be lifted in wooden frame buildings, because they can be readily fastened to the beams. They can be employed for only relatively light machines.

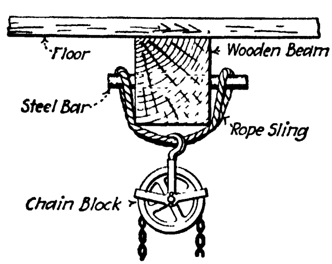


FIG. 132.—Fastening a chain block to a beam with a steel bar and a rope sling.

173. NOTE.—ANOTHER SUPPORT METHOD IS TO BORE A HORIZONTAL HOLE THROUGH THE BEAM (Fig. 132), through its neutral line, and then insert a solid steel bar in the hole. The bar should project on both sides for several inches. A rope sling for attaching the hoist is wrapped around the projecting ends. This method has the advantage that the hole is bored along the neutral axis. In this position the hole weakens the beam less than it would if bored along a vertical line. Another feature, which may be desirable, is that no hole is drilled in the floor above.

174. Hangers Can Be Devised For Suspending Hoists From Structural Steel Members.—One type is shown in Fig. 133. It is constructed from pieces of angle and bar iron stock.

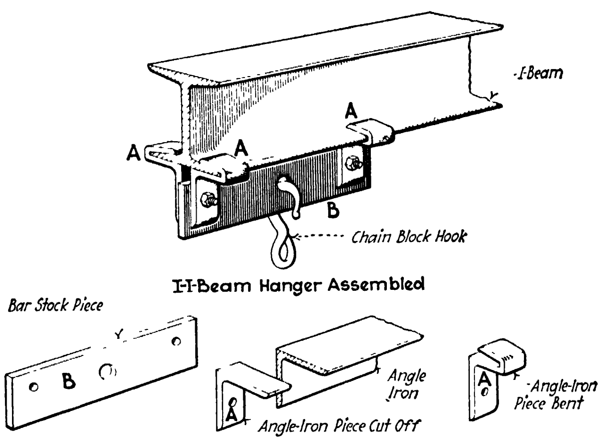


FIG. 133.—An I-beam hanger for supporting a chain block. (CHAS. H. WILLEY, *Southern Engineer*, March, 1923.)

Four pieces are cut from steel angle of suitable size (*A*, Fig. 133-*II*). One leg of each is bent over as indicated. A hole is drilled through the unbent leg of each. A piece of bar stock, *B*, about 8 in. long, is drilled with three holes. A hole is made near each and one is made in the center for the chain-block hook. The four pieces of angle, when bolted to the ends of the bar comprise the hanger. In use it is clamped around the I-beam flange, as shown in Fig. 133-*I*.

175. NOTE.—A DETACHABLE BEAM HOOK (Fig. 134) may be employed for attaching a hoist to a structural steel member. This hook can be

used on overhead channels, I-beams, and angle members. The hook consists of a piece of iron rod, which is bent as indicated in Fig. 134, and which has a lip forged on one end. When the hook is attached to a beam, the load center is not in line with the center pressure; this forces the lip against the beam and keeps the hook rigidly in place. The lip should have a wide face to prevent the hook from swinging sideways. The hook must be made to fit the beam, but, as the beams in a shop are usually of uniform size, one size of hook may be found sufficient. This hook has the advantage that it may be readily installed and removed.

176. NOTE.—FOR ATTACHING A HOIST TO A STEEL TRUSS, all that is required is to wrap a rope or chain sling around the truss and fasten the hoist to it.

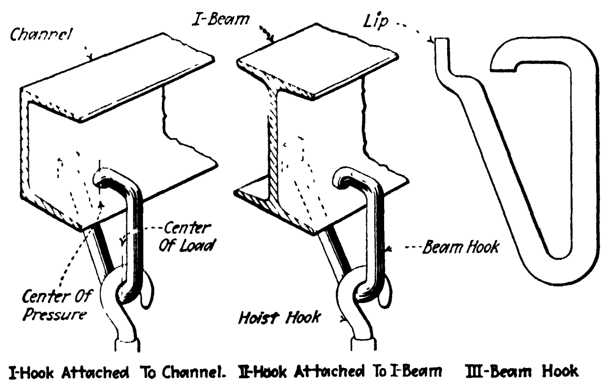


FIG. 134.—A detachable beam hook for supporting a chain block from a steel member.

177. To Suspend A Hoist From Concrete Ceilings, holes must usually be drilled into the concrete. These need not always be drilled entirely through the concrete. They may be drilled in for several inches and anchor shields inserted in them. Then screw eyebolts and screw hooks can be screwed into the shields and the hoists can be suspended therefrom. When such an attachment is not sufficiently strong to carry the load, the method of Fig. 130 (which is always the preferable and safer one) should be employed. That is, a hole should be drilled through the ceiling (floor above). Then a cross-support is laid across the floor, and a nut eyebolt inserted through both the floor and the support. The hoist may then be suspended from the nut eyebolt. In some concrete build-

ings, threaded iron sockets are provided in the ceiling for supporting hoists (Sec. 101) and other equipment.

178. NOTE.—DRILLING HOLES IN CONCRETE CEILINGS FOR HOIST SUPPORTS which will be used only for the installation of a single machine, is not very economical practice. To drill a hole in concrete is a difficult task which requires considerable time (Sec. 207). When installing an electrical machine in a building which has concrete ceilings it is more economical, usually, to build a gallows (Fig. 129), or a similar device, for supporting the hoist. When this method cannot be employed, it may be desirable to roll the machine onto its foundation.

179. For Lifting A Large, Heavy, Assembled Machine Onto Its Foundation a crane must be employed. Where cranes of ample capacity are available, it is a comparatively simple matter to move large machines about at will. Slings should be provided under the heavy parts of the machine (Fig. 30) to prevent excessive strains from being set up in the bedplate. Some machines have holes in their bedplates for which can be used for the insertion of the slings (Fig. 30). When such holes are not provided, the slings can be placed under the bedplate. This, however, requires raising the machine above the floor, before the slings can be inserted under the machine.

180. NOTE.—CRANES ARE NOT ALWAYS AVAILABLE WHERE LARGE MACHINES ARE INSTALLED.—In such cases, the machine is usually jacked up and cribbing built up underneath it. Then it can be rolled onto the foundation as described in Sec. 156.

181. Electrical Machines Installed On Wall Or Column Supports Or On Ceiling Platforms are usually lifted in place by hoists or block and tackle. In the ordinary procedure, the machine is hoisted up between the supports of the platform (Fig. 135) to an elevation above it, before the floor of the platform is laid. The floor is then laid and the machine let down into place. When this method cannot be followed, the machine may be raised alongside the platform (Fig. 136) and then slid along timbers onto the platform. These timbers can be laid on the platform so as to project under the machine. The ends of the timbers may be braced, where necessary, by uprights (*U*, Fig. 136).

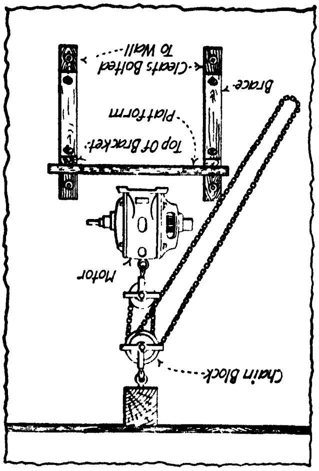


Fig. 135.—Machine is hoisted up between supports before platform is laid and then, after the platform is laid, let down on it.

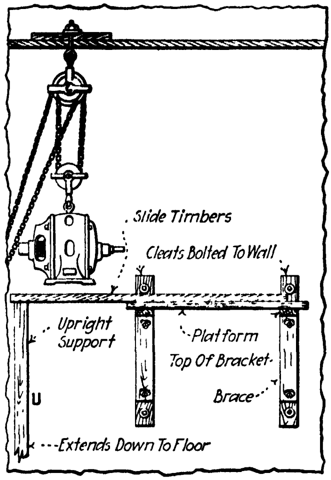


Fig. 136.—Machine hoisted up alongside of support and then slid onto support.

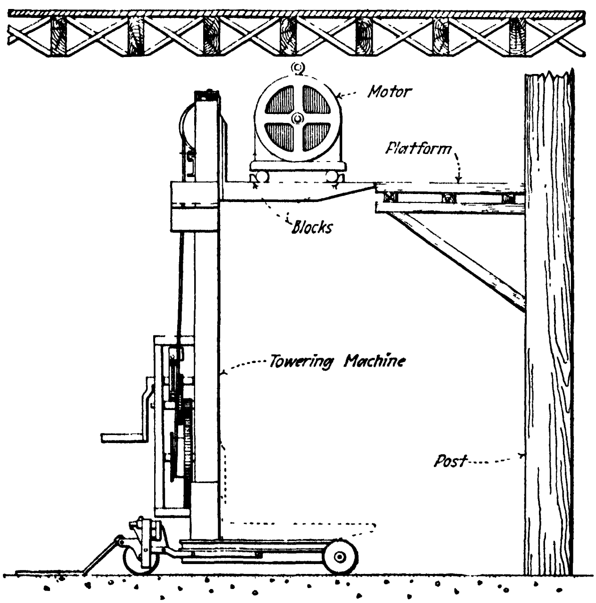


Fig. 137.—Lifting a motor onto a column support with a tiering machine. (Revolvator Co., Jersey City, N. J.)

FIG. 138.—Elevating a 30-hp. motor in the inverted position, to a ceiling support with a tiering machine. (REVOLVATOR Co., Jersey City, N. J.)

FIG. 139.—Motor shown in the preceding illustration held against ceiling ready for attachment. (REVOLVATOR Co., Jersey City, N. J.)

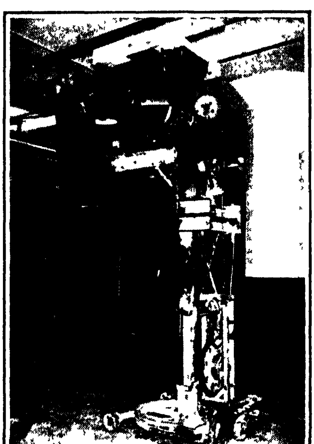


FIG. 140.—Inverted motor elevated to its ultimate position with a tiering machine. Note the motor support of timbers on ceiling. (REVOLVATOR Co. Jersey City, N. J.)

FIG. 141.—Platform being lowered after the motor, shown in the preceding illustration, has been bolted to its support. (REVOLVATOR Co. Jersey City, New Jersey.)

182. NOTE.—WHEN A TIERING MACHINE IS AVAILABLE, it may be employed for raising the machine up to the level of the support (Figs. 137, 138, 139, 140 and 141). The machine then may be rolled from the tiering machine platform onto its support. This is a very convenient method of raising relatively small machines and it should be used when feasable.

183. When Motors Are To Be Mounted On Walls Or Ceilings, The End Bells Or Bearing Brackets Must Be Turned through 90 or 180 deg. respectively. The motors are shipped from the factory for floor mounting, unless otherwise specified. Thus, the bearing brackets must be turned through the cor-

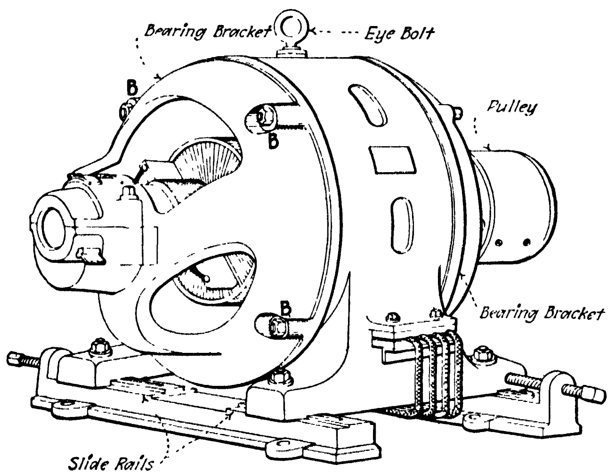


FIG. 142.—Single-phase motor of the bearing bracket type. The four bolts *B* which hold each bearing bracket can be unloosened, the brackets rotated through 90 or 180 deg. and then the brackets can be fastened in the new position (WAGNER ELECTRIC MFG. CO., St. Louis, Mo.)

responding angle in order that the lubricating devices may be restored to their operating position; otherwise all the oil will run out of the boxes. Nearly all motors (Fig. 142) of the end-bell or bearing-bracket type are constructed in such a manner that the end bells can be removed and rotated through 90 or 180 deg. When the end bells are removed, care must be exercised to see that the surfaces of the joints are clean before the end bells are replaced and the bolts tightened; otherwise the bearing alignment may be affected. Motors with bearing

pedestals can seldom be installed on ceilings or walls, unless specially constructed therefor. For some motors, the slide rails for wall or ceiling mounting differ from those for floor mounting. The proper rails should be obtained for each case.

184. NOTE.—IN ROTATING THE END BRACKET, THE RELATIONSHIP BETWEEN THE POSITIONS OF THE BRUSHES AND POLE PIECES MUST BE PRESERVED.—Frequently after a change in the end-bracket position the motor will run in the wrong direction or will not operate at all. This is due to a change in the position of the brushes. There are two conditions which may occur: (1) *The brushes may still be in the neutral positions but the direction of the current through the armature may have been reversed.* (2) *The brushes may line up with the points midway between the pole pieces instead of with the center of the pole pieces or vice versa.* To avoid a change in the brush position, it is desirable, when rotating end brackets, to mark one brush-holder and also the point that is opposite it on the frame of the motor. Then, if after the rotation has been made, these two marks are again brought opposite to each other, there will be no change in the brush position. A 180-deg. rotation on a four-pole machine will not shift the brush position. Consequently, on four-pole machines for 180-deg. rotation, the position of the brushes need not be altered as just described. Another method is to move the brushes backward through the same angle as that through which the brackets were moved forward—or vice versa.

185. The Methods To Be Employed In Lifting Machines To Ceiling Supports will depend on the conditions encountered and the hoisting equipment available. The erection of small motors upon ceiling supports is comparatively simple. But the erection upon ceilings of rather large motors, with ease and without mishap, is often quite a problem. The methods which are described in the following sections have proved satisfactory in certain installations. They are given herein with the hope that they may impart ideas which may be useful or that they may suggest new ideas. The exact arrangements which are herein shown need not necessarily be followed.

186. NOTE.—USUALLY THE BEDPLATE OR SLIDE RAILS SHOULD BE ATTACHED TO THE MOTOR when it is hoisted into place. If, however, the head room is limited or hoisting facilities poor, it may be better to fasten the bedplate or rails to the supports before hoisting the motor.

187. NOTE.—FOR CEILING MOUNTING, A MOTOR WITH A SINGLE BASEPLATE is preferable to one with two slide rails. It is more difficult and tedious to line up and level two slide rails than one baseplate. Also, the slide rails will require at least twice as many supporting bolts as will a baseplate.

188. A Method Of Hoisting Inverted Motors To A Ceiling In Which Holes May Be Drilled is shown in Figs. 143 and 144. This method has been found excellent under certain conditions. In it the inverted motor is raised with two ropes

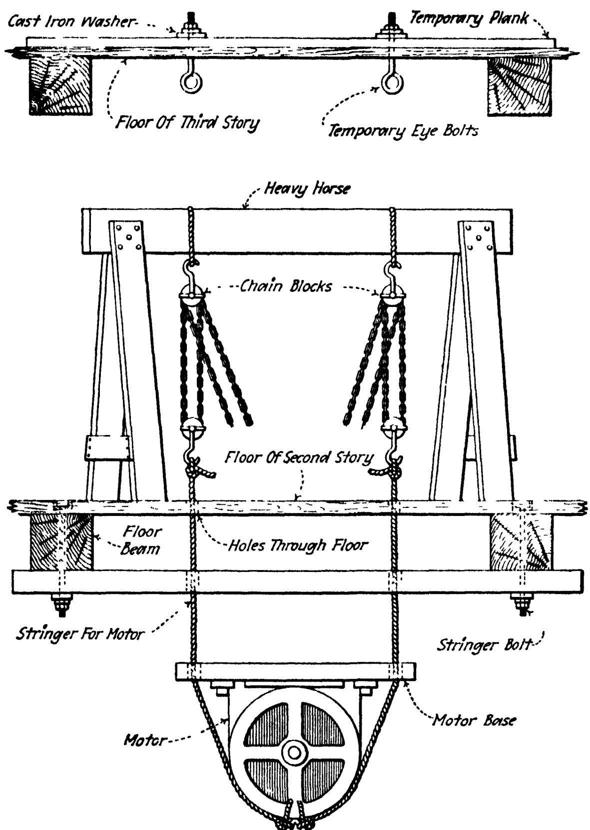


Fig. 143.—Elevation of hoisting arrangement for raising an inverted motor up to stringers bolted to a ceiling beam.

attached to chain or tackle blocks. Each rope, which passes through an anchor-bolt hole in the motor base at diagonally opposite corners, is arranged around the motor frame, and is tied to the eyebolt at what is normally the top of the motor. The ropes then pass through two of the four holes bored

through the hanger timbers and through two accurately located holes in the floor above. On this floor rests a horse which supports the two sets of blocks with which the motor is raised.

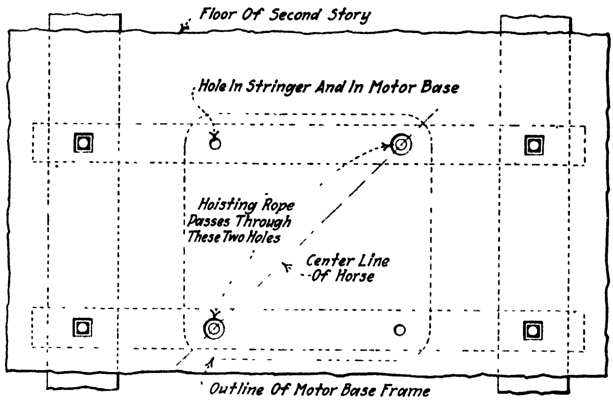


FIG. 144.—Plan view of second floor of hoisting arrangement shown in Fig. 143.

189. EXPLANATION.—As indicated in Fig. 144, the horse is arranged diagonally so that it is directly over the two holes in the floor through which the hoisting ropes pass. When possible, it is desirable to support the hoists from temporary eyebolts fastened to the floor of the story

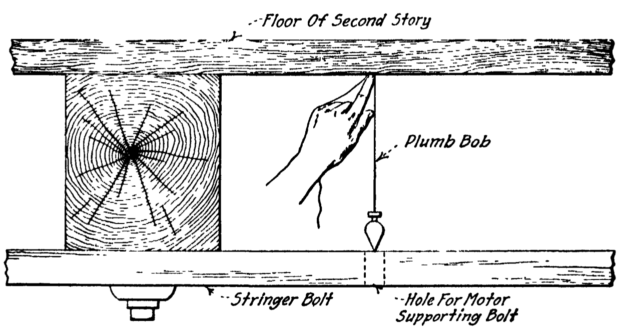


FIG. 145.—Method of locating bolt holes in the floor.

next above as shown at *A* and *A* (Fig. 143) instead of from the horse. With the former arrangement, the motor can be lifted from the floor to the ceiling with one fastening of the hoist. But when a horse is employed, since it is only a few feet from the floor, several fastenings of the hoist to the rope must be made. This necessitates having some means

of holding the motor while the fastening of the hoist is changed. After the motor has been raised to its position on the stringer planks, two bolts are inserted through the open holes and set up tightly. The hoisting ropes are withdrawn and the other two bolts are inserted. It will be noted that with this method it is not necessary to cut any large holes in the floors. An advantage of this method is that the bolt holes in the motor base and in the stringers will line up automatically as the motor is raised into position.

190. Note.—The Two Holes In The Floor Should Be Directly Above Two Diagonally Opposite Holes In The Stringers (Fig. 144). If a bit long enough is available this is easily accomplished by using the holes in the stringers as guides and boring with the lower end of the bit through one of them. When no long bit is available, the locations of the floor holes can be accurately determined with a plumb bob, as shown in Fig. 145. The floor holes should be generously large so that they will not bind the hoisting rope.

191. Note.—Overhead Drilling May Be Done Quickly And Neatly (Fig. 146) with an electric drill and a tiering machine. When a tiering machine is not available, a platform may be built and used instead.

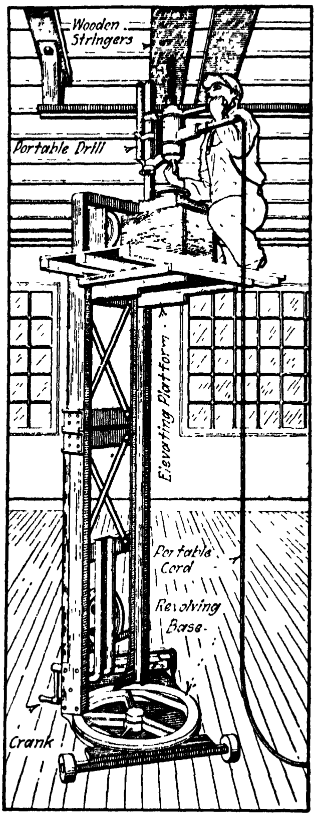


Fig. 146.—Drilling holes in overhead wooden stringer with an electric drill and a tiering machine employed as a support. (Revolvator Co., Jersey City, N. J.)

192. Another Method Of Hoisting A Motor To A Ceiling is shown in Fig. 147. This is similar to that of Fig. 143. The only difference is that the method of Fig. 147 employs roller guides and has the chain blocks installed in the same story with the motor instead of in the story above. In Fig. 147, $\frac{5}{8}$-in. steel elevator cable was employed for hoisting cables, and four cable clamps for holding the machine to the cable. Machines weighing up to 3 tons were successfully handled. The method

can often be employed, where it is not possible to carry the cable to the floor above, by placing the guide rollers on the stringers. It is usually desirable to have two sets of the rollers; one set having 6-in. pulleys, and the other 3-in. pulleys. The smaller pulleys should be used on top of the stringers

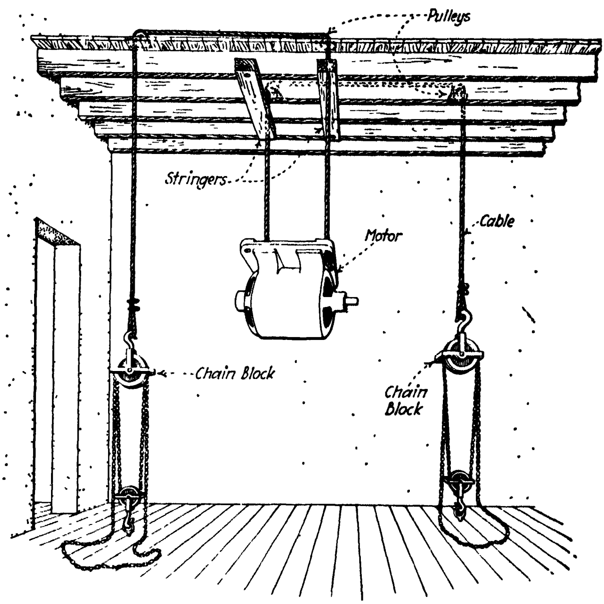


FIG. 147.—Method of raising an inverted motor to ceiling stringers and having the hoists on the same story with the motor. (LEROY A. FRANCIS, *Electrical Record*, Sept. 1920.)

whenever it is not possible to carry the cables to the floor above. Details of the roller guides are shown in Fig. 148.

193. NOTE.—ON COMPARING THE TWO METHODS JUST DESCRIBED, it will be noted that the latter requires rollers while the former does not. As it takes considerable time to make these rollers (Fig. 148), it is seldom economical to employ the latter method when only one machine is raised. In some cases, however, as when holes cannot be cut in the ceiling, the former method cannot be utilized. Also the latter method has an advantage over the one using the horse for a support (Fig. 143), in that with it one fastening of the hoists to the lifting cables is required while with the other several are required. Where eyebolts can be installed in the ceiling

of the story above, only one fastening of the hoists is necessary with the former method. This seems to be the most desirable method since with it no rollers are necessary. When many machines are installed, the same rollers may be employed many times, and in such cases the latter may be the more economical.

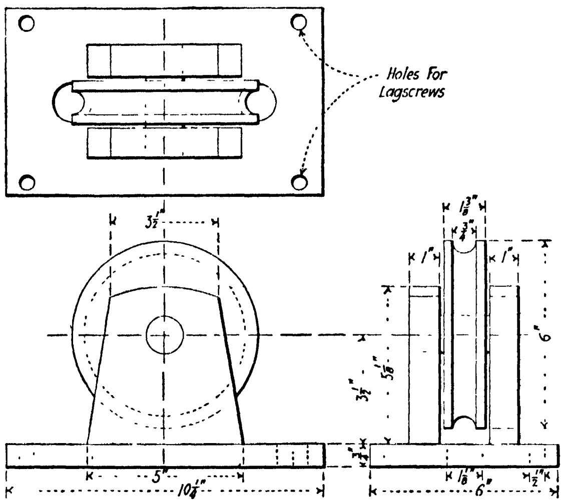


FIG. 148.—Details of cable roller guide employed in the method shown in Fig. 147. (LEROY A. FRANCIS, *Electrical Record*, Sept., 1920.)

194. A Platform And Screw Jacks May Also Be Employed For Raising A Motor To A Ceiling Support (Fig. 149).—The motor is raised with a chain block, as illustrated in Fig. 149, into the cradle on the platform. The cradle consists of a wooden frame made of 2- by 10-in. planks, the top sides of which are curved to fit the frame of the motor. Pipe rollers should be placed under the cradle so that the motor can be easily moved under its proper position. The cradle and motor then are jacked up until the motor is against the ceiling support.

195. A Method Of Hoisting A Motor To A Ceiling In Which Holes May Not Be Drilled is shown in Fig. 150. In this installation the building has a concrete roof supported by steel I-beams spaced 16 ft. on centers. The motor was suspended from two stringer I-beams which were bolted to the roof beams. The holes for the motor bolts were drilled in the

stringers in their proper positions. Short pieces of 2-in. blocking were piled on top of the stringer I-beams, a short distance outside of the locations where the motor end brackets would come (Fig. 150). On these blocks, midway between the

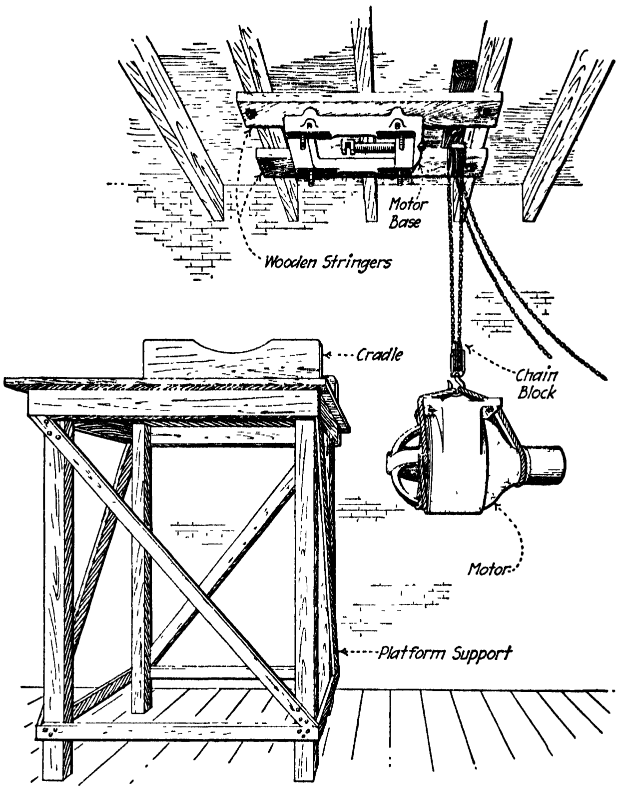


FIG. 149.—Raising a motor to a ceiling support by employing a platform, cradle, and screw jacks in conjunction with a chain block. (K. A. REED, *Power*, Sept. 21, 1920.)

stringers, was laid a steel bar, 1½ in. in diameter. Onto this bar were hooked two one-ton chain blocks. The motor end brackets were then rotated through 180 deg. and the motor inverted. The hooks of the two chain blocks were attached directly to the motor housing. The motor raised to its proper

position against the stringers. The anchor bolts were inserted and the motor fastened in position. The pulley was not on the motor when it was raised.

196. NOTE.—WHEN THE HOOK CHAINS OF THE CHAIN HOISTS ARE NOT LONG ENOUGH TO REACH THE MOTOR on the floor, the following method may be employed. Two chains, one attached to each hoist hook, can be fastened to the motor and the motor lifted with the hoists. After the motor has been lifted sufficiently high so that the hoist hooks will reach it, a third chain can be slung over the I-beam and hooked to one end bracket. The near chain block can then be lowered off and released

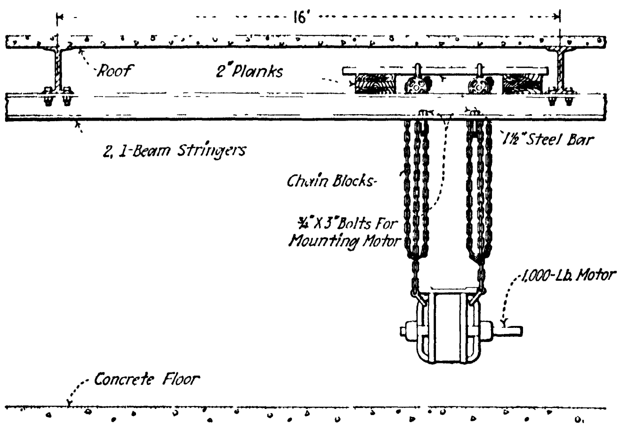


FIG. 150.—Arrangement for hoisting a motor to a ceiling in which no holes could be bored. (H. S. RICH, *Industrial Engineer*.)

from its extra chain. The chain-block hook may then be hooked directly to the end bracket. This can then be repeated for the other chain block. Then, the motor can be raised in the usual manner.

197. To Lift A Motor To A Ceiling In A Concrete Building, it is often necessary to build a heavy, timber frame (Fig. 151) for supporting the chain blocks. It is so difficult to drill holes in concrete that it is generally more economical to build a frame than it is to drill the holes. Such a frame is shown in Fig. 151. The chain blocks are suspended from the frame. The inverted motor is supported on a timber cradle or platform. This cradle has a railing around the motor to prevent it from sliding off. The strips A, prevent the motor from turning. The entire cradle is then hoisted up by the two chain blocks

until the motor base is against the ceiling. The motor should, by plumbing down with a plumb line, be set in such a position on the cradle that the bolt holes, in its base, line up with the bolts in the ceiling.

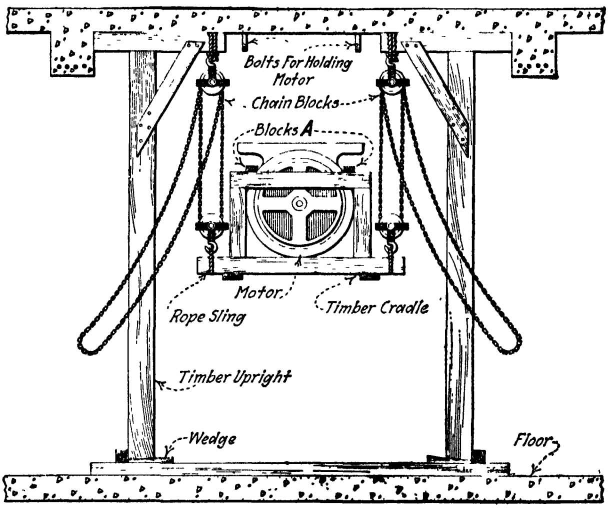


FIG. 151.—Raising motor to a ceiling in a concrete building by means of a framework supporting the chain blocks.

198. NOTE.—CAREFUL MEASUREMENTS SHOULD BE MADE when employing the above method, or whenever a cradle is used, to be certain that the chain blocks will raise the motor into its final position. That is, with the two sheave blocks close together, the cradle should be raised sufficiently high so that the motor base will go into position over the bolts.

199. Some Concrete Buildings Have Threaded Iron Sockets, provided in their ceilings, for supporting and erecting machinery. When such sockets are installed, steel, screw eyebolts should be obtained and screwed in the sockets. The motor can then be raised as shown in Fig. 152. The cradle illustrated in Fig. 151 could be used but, in this case, the one shown is better adapted. It is low enough to allow for the sheave blocks when the motor is against the ceiling and also is very stable.

200. Note.—A Tiering Machine Is Well Adapted For Raising Motors To The Ceiling.—When a tiering machine is available (Fig. 138), the motor can be set upon it in the inverted position and blocked to prevent slipping and turning. Then with the tiering machine, the motor can be raised into the desired position.

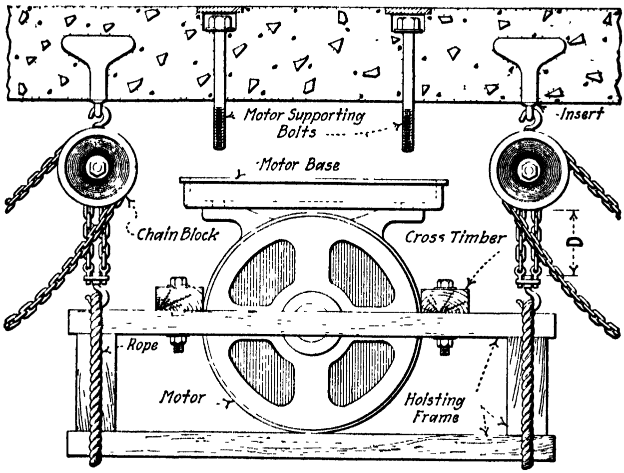


Fig. 152.—Arrangement for raising motors to the ceiling when threaded sockets are provided. Care must be exercised to insure that the distance *D* will be sufficient, after the motor has been raised to position, to insure that the anchor bolts will pass through the bedplate so that the nuts may be turned on. (H. Winfield Secor.)

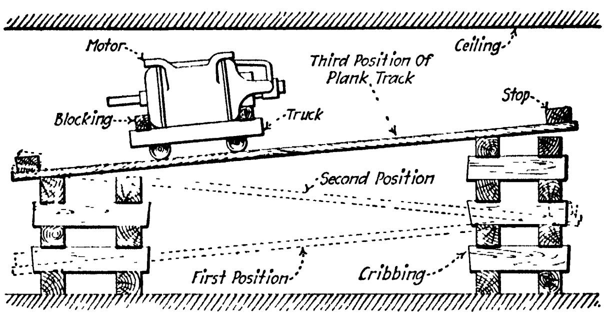


Fig. 153.—Method of erecting a ceiling-suspended motor without tackle.

201. Note.—To Raise A Motor To A Ceiling Without Tackle, the expedient which is illustrated in Fig. 153 may be employed.[1] The motor is mounted, inverted, on a four-wheel shop truck. The truck—motor on it—is then rolled to the highest point of a plank track, one end

[1] Rich, I. B., *American Machinist* Oct. 4, 1923.

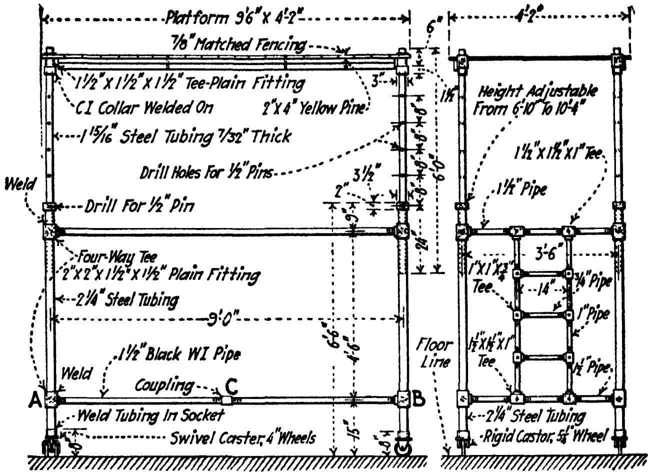


FIG. 154.—Portable staging constructed of steel tubing or iron pipe. Black iron pipe is quite as satisfactory as tubing. When working above machines, the bottom rail AB may be taken out by unscrewing the right-and-left coupling C, so that the staging may straddle the machines (L. B. C. in *Industrial Engineer*, July, 1923).

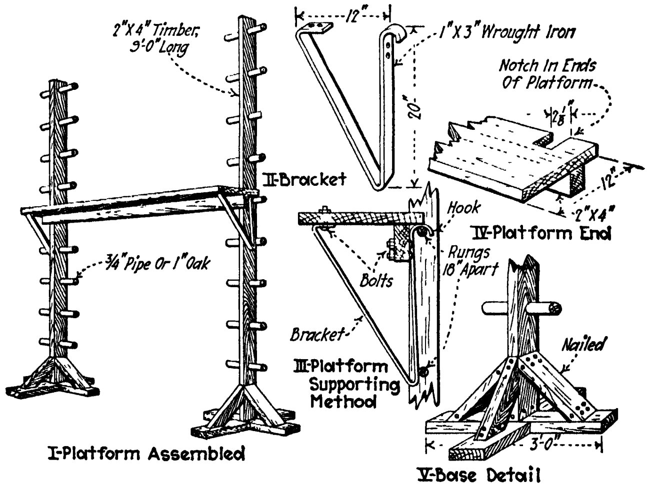


FIG. 155.—Wooden erecting platform for light work. The uprights may be used separately as ladders. (G. A. LUERS in *Popular Mechanics*.)

of which has been blocked up. Then the other end of the track is blocked up to twice the height of the first end. The truck is now rolled over to this other end. This process is repeated until the motor has been raised to the ceiling.

202. Portable Platforms Or Stagings Are Desirable When Erecting Ceiling-Mounted Motors.—Figures 154, 155, 156, 157 and 158 illustrate various types of platforms which have,

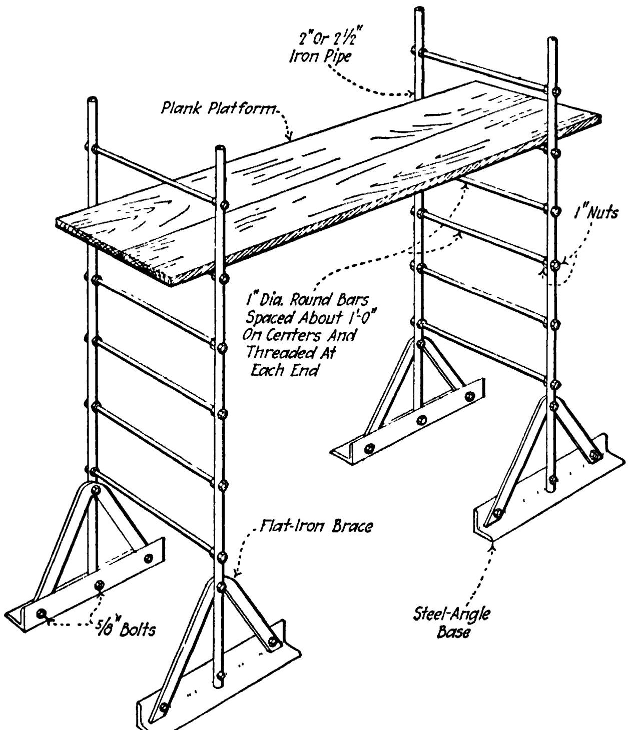


FIG. 156.—Iron pipe and structural-steel platform supports.

for different conditions, proved successful in electrical machinery erection.

203. To Lift A Motor Into Position On A Wall, the arrangement shown in Fig. 159 may be employed. An eyebolt is secured in the ceiling above the place of installation. The center of gravity of the machine is determined approximately

and the eyebolt so located that it will be directly above the center of gravity of the machine when it is installed. The end brackets of the motor are rotated through 90 deg. The motor is laid on its side on the floor. A rope sling is then placed around the motor and it is hoisted into position. The sling should be so arranged that two ropes encircle the motor.

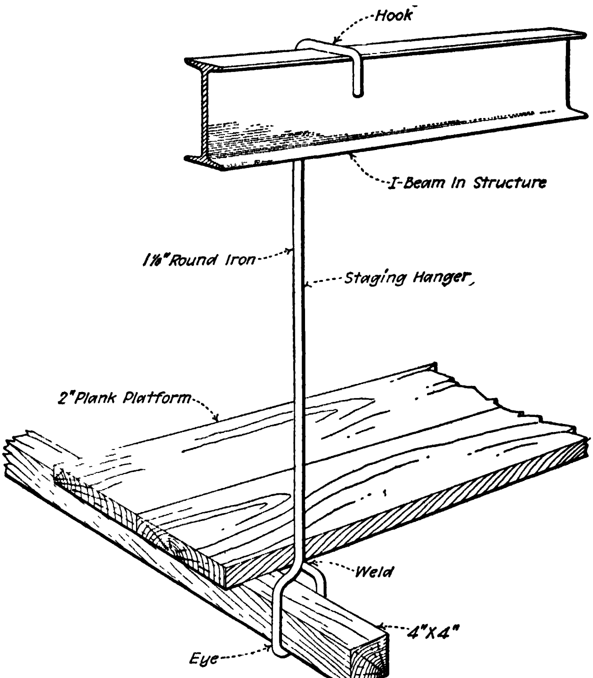


FIG. 157.—Staging hanger for supporting an erection platform.

These should be drawn tight and the loop in the sling for attaching the hoist hook should be located over the center of gravity of the machine. This prevents the motor from swinging out of line. The ropes around the motor should be so placed that they will clear the cleats which are mounted on the wall for fastening the motor. If the lower anchor bolts, which hold the cleats to the wall, tend to interfere with the raising of the motor, they can be omitted temporarily and later installed after the motor has been raised above them.

204. NOTE.—ANOTHER METHOD OF LIFTING A MOTOR INTO POSITION ON A WALL is shown in Fig. 160. In this method the sling is fastened through the end brackets of the motor. When the motor is raised up to the timber cleats, it can be pulled out so that the base passes over the vertical surfaces of the cleats. When the motor reaches its proper position, the two upper bolts or lagscrews can be inserted and tightened up a little. Then the motor can be let down until its base is against th cleats. The lower two bolts or lagscrews may then be inserted an drawn up.

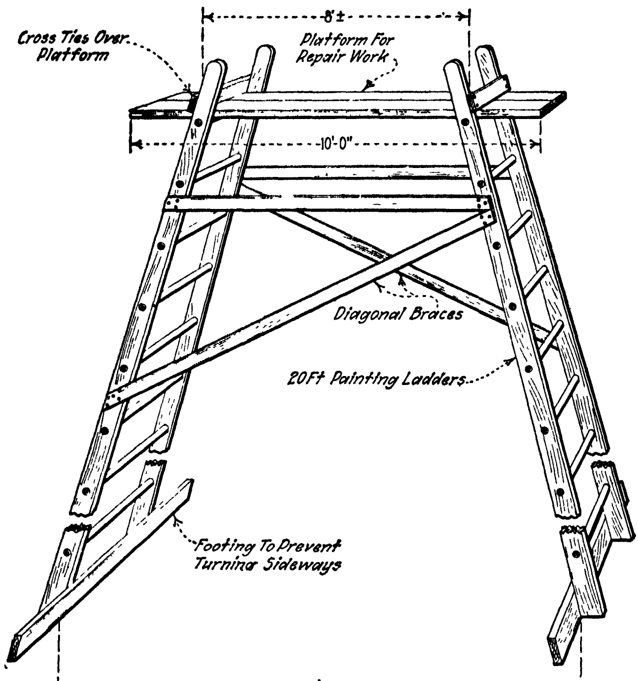


FIG. 158.—High working-platform improvised from two 20-ft. painting ladders. (G. A. Luers in *Power Plant Engineering*, April 1, 1923.)

205. Most Motors And Generators Are Held To Their Frame Supports Only By Anchor Bolts Or Lagscrews; when mounted on foundations they are ordinarily, in addition, grouted (Sec. 385). Holes are provided in the baseplate, feet, or slide rails (whichever may be the case) of the machine for the insertion of the lagscrews or bolts. Lagscrews are often employed for holding the smaller machines; bolts are always

preferable for both the small and the medium-sized machines. Through-going bolts are always preferable to lagscrews. When mounting machines the holes in the support for the supporting bolts are usually drilled before the machine is in place. Sometimes, however, it is desirable to drill them afterwards, especially when it is difficult to determine the exact location of the motor bolt holes before the motor is lifted into position. When mounting motors on steel members, bolts

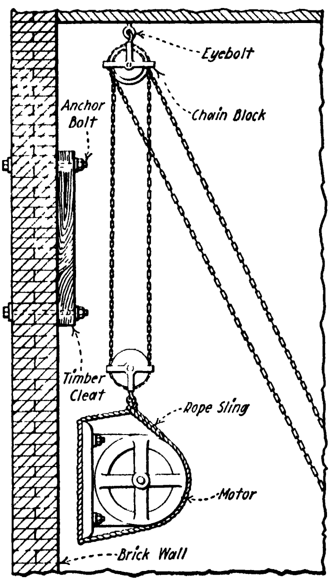


FIG. 159.—A method of lifting a motor into position on a wall.

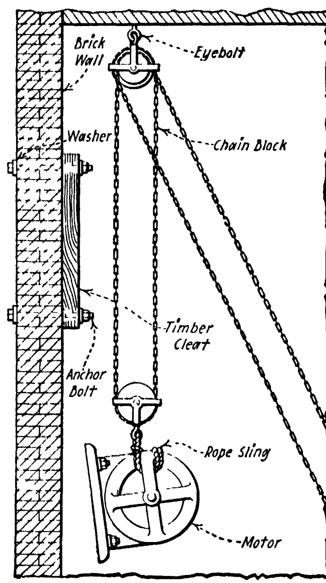


FIG. 160.—Lifting a motor into position on a wall by placing a sling around the end brackets.

must be employed. For mounting motors on concrete, lagscrews may be used in connection with expansion shields (Sec. 95). The various methods of fastening machines to their supports are described and illustrated in Div. 2. Secs. 49 to 119.

206. NOTE.—LARGE ELECTRICAL SELF-CONTAINED UNITS SUCH AS MOTOR-GENERATOR SETS ARE EQUIPPED WITH BEDPLATES in which, often, no bolt holes are provided. Such machines are ordinarily set on concrete or masonry foundations and have their bedplates grouted to

the foundations (Sec. 353). They do not require as strong a bond to the foundation as does a machine delivering or receiving power by belt gears or by direct connection to a shaft.

207. Drilling Holes In Concrete With A Chisel Or Drill And A Hammer is a difficult task. By this method an hour of a laborer's time is required to drill about 1 ft. of small-diameter hole in concrete. The "cross" drill bit (Fig. 161) is ordinarily used, although drills of various other shapes may be employed. Best results will be obtained with drills which do not have too hard a cutting edge, because such drills break readily. It is good practice to use a rather soft drill and harden it a little

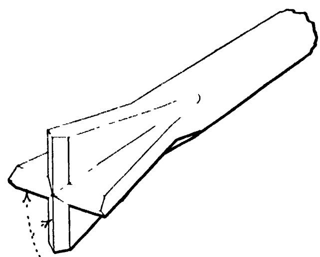


FIG. 161.—A "cross" drill bit.

more if necessary as the cutting proceeds. Just as small and as short a drill should be used as will suffice to make the hole large and long enough for the purpose. After each time the drill is struck, it should be rotated slightly so that its cutting edges will not be in the same position when the next blow is struck.

208. EXPLANATION.—For drilling the first part of a hole, a heavy drill, of the full size of the hole, may be used, as the concrete will withstand the strain. But when the bit is about breaking through the concrete, then it is desirable to use a small-diameter light drill. If a large, heavy drill is used for drilling through, the lower edge of the hole is apt to be broken away as shown at *C* of Fig. 162. Although such a break may be repaired, it takes time for the new cement to harden; the resulting job will not be as neat as when a clean hole is cut entirely through the concrete as at *F*. A piece of timber, *D*, placed under the location where the hole is to be made (and set up solid with a jackscrew or a lever, made as shown in Fig. 162) will prevent most of the chipping of the concrete when the drill breaks through the lower surface. After the small drill has cut

through the concrete, the hole may be enlarged very readily with the larger drill and without much danger of cracking off the under side of the hole. It is well, however, to keep the supporting timber in place until the hole has been completed with the large drill.

209. NOTE.—WHEN DRILLING HOLES THROUGH CONCRETE OR MASONRY WALLS, the same precautions should be observed. The smaller drill and the timber support should be employed for breaking through the

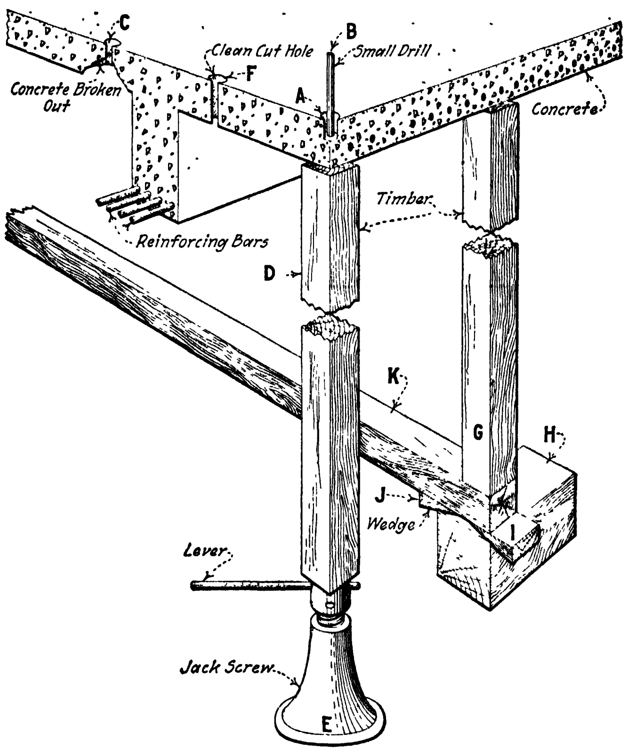


FIG. 162.—Drilling holes in concrete with a chisel and a hammer. (JAMES F. HOBART, "Millwrighting," P. 129.)

surface—unless the hole can be accurately located on both sides of the wall in which case the drilling may be done partly through from either side of the wall. The timber can be removed after the small drill has pierced the wall. The larger drill should be used through the side of the wall opposite from that through which the hole was started.

210. AN UPRIGHT CAN BE SET SOLID AGAINST THE CEILING WITH A LEVER (Fig. 162), by the following procedure: Place a block, *H*, under the lever timber. Then, raise the far end of the lever so as to enable

wedge J to be inserted between the timber lever and the block. Depress the far end of the lever as far as possible and insert wedge I. Raise the far end of the timber again and push in wedge J as far as it will go. Then the operation is repeated again at wedge I. After performing the operation several times, the upright should be tight against the ceiling.

211. An Anchor Shield Hole Should Be Chambered Out At Its Bottom.—That is, the diameter of the hole at the bottom should be larger than that at its top. To accomplish this for a small hole, a chambering tool or a thin chisel slightly bent should be employed. Using the bent chisel permits one to cut the side of the hole at its bottom without breaking off the top edge of the hole.

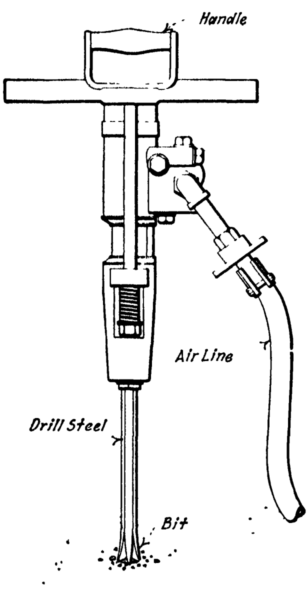


FIG. 163.—A self-rotating, hammer pneumatic drill. (McKiernan, Terry Drill Co., New York City.)

212. When Many Holes Are To Be Drilled In Concrete, It Is Desirable To Use A Pneumatic Or An Electric Drill.—With a pneumatic drill about 15 to 16 ft. of hole can be drilled in an hour. These drills (Fig. 163) obtain their reciprocating motion by the application of compressed air, alternately to the front and back ends of a piston. There are two types of pneumatic drills: (1) *The piston type.* (2) *The hammer type.* In the piston type, the drill steel is clamped rigidly in a chuck which is attached to the piston rod of the drill and is reciprocated by the movement of the piston in the cylinder. By properly "feeding" the drill, the bit is made to strike the rock on each forward stroke of the piston. In the hammer type (Fig. 163), the drill steel does not reciprocate, but the piston is so designed that a blow is struck against the shank end of the drill steel on each forward stroke of the piston. The force of

the blow is conveyed through the drill steel to the bit. In "feeding" the drill, the bit should be held lightly against the concrete. Drills of both types are provided with an arrangement that rotates the bit after each blow is struck. When compressed air is not available an electric drill may be employed.

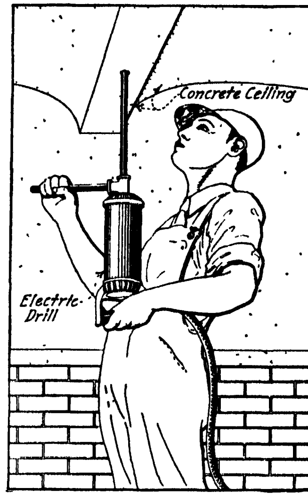


FIG. 164.—Drilling hole in a concrete ceiling with an electric drill. (NATIONAL ELECTRIC MFG. Co., Pittsburgh, Pa.)

213. NOTE.—THE PENETRATION SPEED OF ELECTRIC DRILLS varies with their design. That shown in Fig. 164 can drill about 15 ft. of 1-in. hole per hour. The drill illustrated may be designed for either 25- or 60 cycle alternating current. With 60 cycles it gives 3,600 blows per minute. The drill has only one moving part, a steel piston which is given a reciprocating motion by an alternating-current magnet. The piston strikes the cutting tool's shank and the force is transferred to the cutting edge. The average power consumption of the drill shown is about ½ kw.

214. A Hand Operated Breast Drill For Drilling Concrete is shown in Fig. 165. With this machine, small holes can be drilled in concrete with considerably greater speed than they

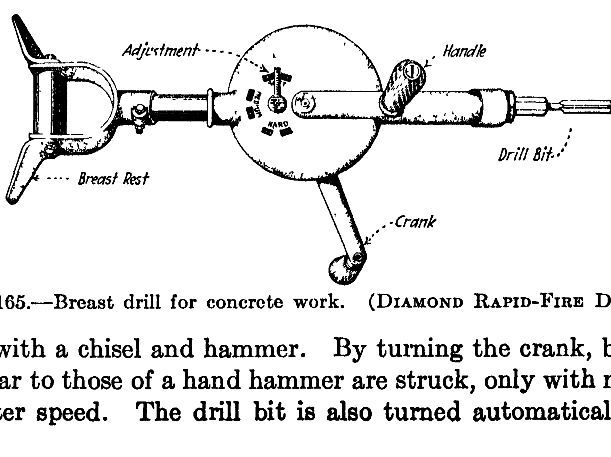


FIG. 165.—Breast drill for concrete work. (DIAMOND RAPID-FIRE DRILL.)

can with a chisel and hammer. By turning the crank, blows similar to those of a hand hammer are struck, only with much reagter speed. The drill bit is also turned automatically in

the hole after each blow. No vibration is felt by the operator. The drill has an adjustment whereby the force of the blow can be regulated so that a hard, medium, or light blow, whichever is desired, will be struck. Drill bits with special shanks (Fig. 166) must be used with the drill.

215. NOTE.—A CEILING STAND WHICH CAN BE EMPLOYED WITH THE DRILL (Fig. 167) will greatly increase its efficiency when drilling ceilings. The stand is made of telescopic sections. These permit adjustment for any height of ceiling, from 7 to 20 ft. Two sizes of stands are made; one for heights of from 7 to 12 ft. and the other for heights of from 8 to 20 ft.

216. In Setting A Large, Completely Assembled Machine on a foundation, great care should be taken to prevent any excessive strains being set up in the bedplate. When the machine is set on the foundation with a crane, slings must be placed under the bedplate at the heavy parts of the machine (Sec. 9). The machine should be let down on iron wedges or level ing plates (Sec. 451) that are closely spaced in a manner so as to divide the weight equally between them. The inside flange of the base should be wedged up under the pillow blocks to prevent their leaning in or out. When the machine is rolled onto the foundation, plenty of rolls should be employed.

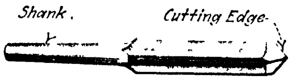


FIG. 166.—Drill bit for breast drill of Fig. 165.

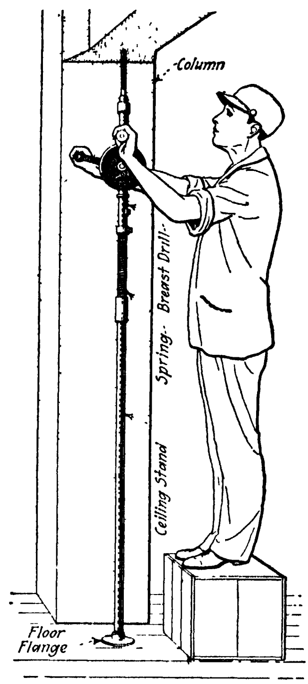


FIG. 167.—Drilling a hole in a concrete ceiling with a breast drill and a ceiling stand. (DIAMOND RAPID-FIRE DRILL.)

In lowering the machine from the rollers onto the iron wedges or leveling plates, the top of the bedplate should be kept always as straight as possible—it should not be distorted so as to minimize the strains which will be set up in the bedplate. The process of leveling, aligning, and grouting in the bedplate is described in Div. 4.

217. The Erection Of An Electrical Machine That Is Shipped Disassembled usually requires a great deal of care and knowledge of the particular machine that is being installed. Each make and type of machine is a little different in construction from any other and thus must be erected accordingly. It would require too much space, and it would not be desirable to describe herein, the method of erecting every type and make of machine. Only the main principles that should be followed together with some of the erecting details for the more common machines are described in this book. The details of erecting a machine of a certain type can often be obtained from the instruction book that the manufacturer sends with the machine. Most manufacturers will send you, upon your request, such an instruction book for any of their machines. The larger machines generally are installed under the direction of an erecting engineer who is sent from the factory. The erection of these large machines requires expert supervision and should not be done by a person unless he has had considerable experience in that line.

218. NOTE.—DISASSEMBLED MACHINES USUALLY ARE DIVIDED FOR SHIPMENT INTO THE FOLLOWING PARTS.—A frame either in one piece or two pieces, and sometimes with separate feet; bearing pedestals; bedplate or soleplates; rotor and shaft; and (on machines with commutators) the brush supports and rigging. Machine sets containing two units have two frames and sometimes two shafts. Alternating-current machines generally have an exciter sent with the machine.

219. There Are Three Methods In Use Whereby Electrical Machinery Which Is Shipped Disassembled Is Supported on its foundation: (1) *With cast-iron bedplate.* (2) *With soleplates.* (3) *With rails and soles.* Bedplates are provided with most electrical sets and with some of the smaller motors and generators. Soleplates (Fig. 168) are most commonly used with direct-current motors and generators as with these

machines, it is not necessary to provide means for quickly adjusting the stator relatively to the rotor. They are also used on some of the larger electrical sets. Soleplates (Fig.

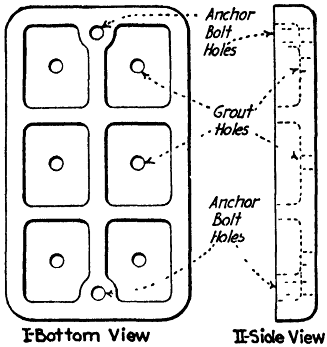


FIG. 168.—Soleplate for a large machine.

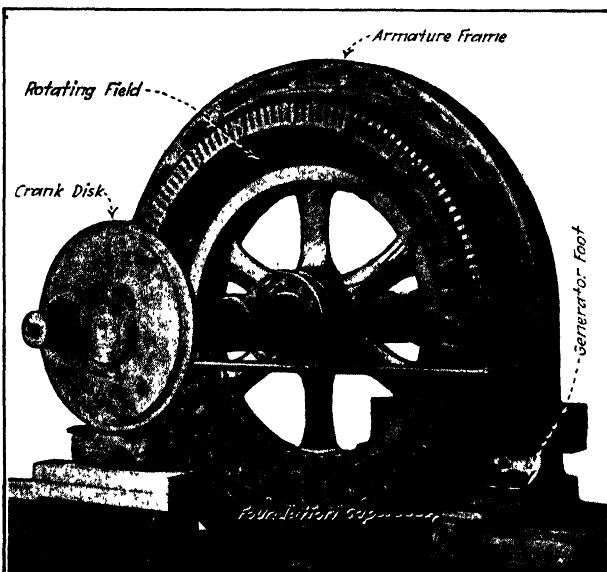


FIG. 169.—Soleplate (or "foundation cap") in position under generator foot. (GENERAL ELECTRIC CO. photograph No. 242,254.)

169) merely are cast-iron bearing plates which, when grouted in position, form a smooth surface on top of a foundation, upon

which the feet of the machine can rest. They also distribute the weight over a larger area. The anchor bolts extend through the machine frame, soleplate, and down into the foundation the usual depth (Fig. 170). Rails and shoes (Fig. 171) are furnished with practically all engine- and coupled-type alternating-current machines except those that are small enough to be handled readily as complete units. The rail and shoe construction permits the accurate and speedy alignment of the stator after it has been shifted along the shaft to permit inspection or repair of armature or field coils.

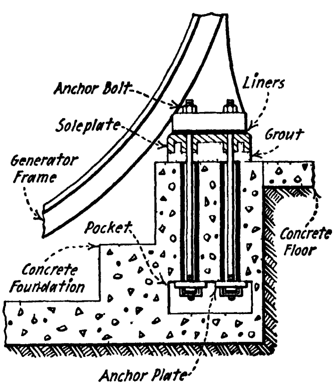


FIG. 170.—Cross-section of a soleplate installed.

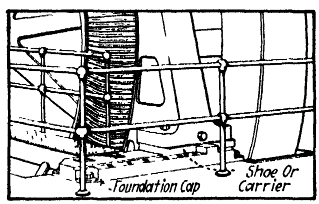


FIG. 171.—"Shoe-and-rail" support for engine-type alternator.

220. NOTE.—THE METHODS OF ERECTING DISASSEMBLED MACHINES OF VARIOUS TYPES are essentially the same, but they do differ to some extent depending on the type of the support of the machine. In this division the various steps in the erection of machines of the bedplate type are described. When the erection of machines either of the other two types differs from this method, such differences are noted.

221. The Erection Of A Disassembled Machine Naturally Should Start With The Base.—The base or bedplate must first be set upon the foundation. Then it must be caıefully leveled, aligned, and grouted to the foundation surface as described in Div. 4. These machines are always of large size and must be grouted to their foundations. Either concrete or masonry foundations should be used; concrete being the material most commonly employed. When the top of the foundation is fairly smooth, as is the case with concrete foundations, its surface should be roughened along an approxi-

mate outline of the bedplate. The roughened surface provides a better bond between the foundation and the grout. The amount of roughing will depend on the character of the machine and the service for which it is intended. It is a good practice, when a good bond between the foundation and the grout is desired, to dig a few pockets in the foundation under the bedplate, as shown in Fig. 258. The top of the foundation should be cleaned thoroughly, using special care to remove all dust and small particles from the pockets. The bedplate can then be lifted onto the foundation.

222. Note.—In Erecting An Electrical Machine Which Is Provided With A Soleplate Or Shoe-And-Rail Support, the soleplates or rails often are not grouted to the foundation until the machine is properly aligned with some existing unit. See Div. 4 for description of the methods of aligning, leveling, and grouting soleplates.

223. The Bedplate Is Lifted Onto The Foundation And Leveled after the foundation top has been cleaned. Usually

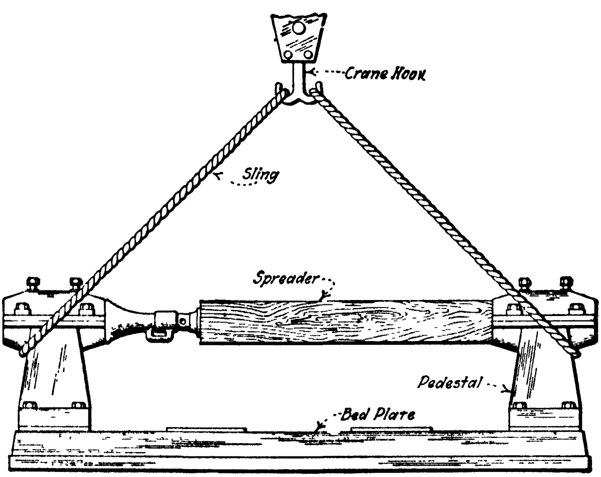


Fig. 172.—Lifting a bedplate by placing slings under the ends of the bearing pedestals and inserting a spreader and screw jack between the bearings.

a crane or hoist is employed for the lifting. Several slings should be placed around the bottom of the bedplate to hold it. Some machines, as for example the Westinghouse synchronous converters, have four holes in the sides of the bedplate for inserting two slings (Fig. 9). When no crane is available,

the bedplate can be jacked up alongside the foundation and cribbing built underneath it. It can then be rolled onto the foundation from the cribbing (Sec. 156). Before the bedplate is let down into position on the foundation, iron wedges or leveling plates (as described in Div. 4 and shown in Fig. 257) should be placed underneath it (Fig. 258).

224. NOTE.—IN LIFTING THE BEDPLATE ONTO ITS FOUNDATION, do not lift it with slings placed under the ends of the bearing pedestals unless a heavy spreader is used between them, as in Fig. 172. If a spreader were not employed, the base or pedestals might be badly distorted or broken.

225. After The Grout Under The Base Has Set, The Bearing Pedestals Should Be Put In Position And The Alignment Of The Bearings Should Be Checked as explained in Sec. 423. Before placing the pedestals in position, the machined surfaces of the bedplate upon which the pedestals rest should be cleaned. The bottoms of the pedestals also must be cleaned. The bearing pedestals and the bedplate are usually marked so that adjacent parts have the same marking. Care should be taken in assembling to insure that the marking of all parts corresponds. The heights of the pillow blocks are adjusted at the factory with sheet-iron or fiber shims. When shipped to the point of erection these shims are tied in bundles and marked so that their proper locations on the base can be identified. With the shims in place, bolt down the pillow blocks. On some machines (Westinghouse Converters) a lateral alignment of the pedestals is unnecessary; this adjustment is made at the factory and the pedestals are ream doweled to the bedplate. On other machines, the bearing pedestals must be aligned (Div. 4) and then doweled to the base, by drilling holes in the bedplate at the proper places. In either case, the alignment of the bearings themselves should be checked because it is important that this be correct to within a few thousandths of an inch.

226. NOTE.—ON SOME ELECTRICAL MACHINES, ONE PEDESTAL is insulated from the bedplate (Fig. 173). Under certain conditions of operation a difference of potential is established along the shaft. This would cause current to flow through a circuit composed of the shaft, bearings, pedestals, and bedplate. This current may be sufficiently

large to pit the shaft and journal and cause bearing trouble. To prevent this, one of the bearing pedestals is insulated from the bedplate. The pedestal and insulation which have the same numbers should be assembled together. When the insulated dowel is driven to position, it is essential that the *micarta* tube cross the joint between the pedestal and the bedplate. Always be certain that there is no bare part of the insulated pedestal touching the bedplate.

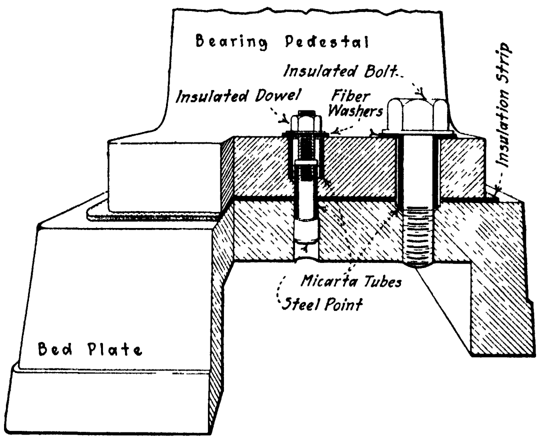


FIG. 173.—Method of insulating bearing pedestal from bedplate used on Westinghouse frequency changers. (WESTINGHOUSE ELECTRIC & MFG. Co., *Inst. Bk. No.* 5176.)

227. Bearing Pedestals Are Usually Lifted Onto The Bedplate with a crane or a hoist. When the pedestal cannot be swung into place with a hoist which is supported at one stationary point a movable hoisting arrangement, as an *A*-frame (Fig. 22), a gallows frame (Fig. 129), a gin pole (Fig. 174) or a crane must be employed. Two hoists suspended from two separate stationary supports (Figs. 127 and 128) may also be employed for swinging the parts into place. The pedestal may be attached to the hoist hook with a rope sling, which can generally be slipped around the bearing housing. The upper halves of the bearing housings of some pedestals are provided with eyes. By bolting the cap in place, the complete pedestal may be lifted by such an eye.

228. NOTE.—WHEN NO HOISTING EQUIPMENT IS AVAILABLE, the pedestal must be jacked up onto blocks and then rolled onto the bedplate.

229. On A Machine Which Has A Frame Shipped In Halves, The Lower Half should be placed on the bedplate after the bearing pedestals are in position. Before placing the lower half of the frame in position, the machined surfaces of the bedplate upon which it rests and the bottom of the frame should be thoroughly cleaned of all protecting grease. The adjacent parts of the frame feet and the bedplate usually have the same identifying mark on them. Care should be taken that the adjacent marks are the same. On the Westinghouse machines consecutive numbers (adjacent parts having the same numbers) are employed as identifying symbols. The height of the frame is usually adjusted at the factory with shims. When these liners are shipped in one bundle, one-half of them should be placed under each foot. When two bundles are shipped, they are so marked that their proper locations can be identified. With the liners in place, bolt down the frame. On most machines the air gap must be adjusted (Sec. 421) before the frame is doweled in place. On some machines (self-contained Westinghouse Converters) the lateral adjustment is made at the factory and the frames are ream doweled to the bedplate This renders further adjustment, when installing, unnecessary.

230. NOTE —THE FRAMES OF DIRECT-CURRENT MACHINES AND OF THE DIRECT-CURRENT UNITS OF SETS are shipped usually in halves. The stator frame of an alternating-current machine or of the alternating-current unit of a set is usually of one piece. If it is shipped in halves, it will be necessary to connect the coils across the split in the frame, either before the motor frame has been placed in position on the bedplate, or with the stator frame shifted clear of the rotor.

231. The Lower Half Of The Frame Is Usually Placed In Approximate Position On The Bedplate Or Soleplates With A Hoist Or Crane.—A grip can be obtained on the frame by slipping slings around its bottom (Fig. 175) and attaching them to the crane or hoist hook. Sometimes when an eye is provided in the top half of the frame, the upper and lower parts are bolted together and both are lifted by the eye After the frame is in position, the top section is removed. For raising large frames, a crane generally must be employed. For lifting the smaller frames, a chain hoist or a block and tackle

can often be used. It is often desirable to employ some movable hoisting device, such as an A-frame (Fig. 22), or a gin pole (Fig. 174). The arrangement that should be used will depend on the equipment available and the local conditions

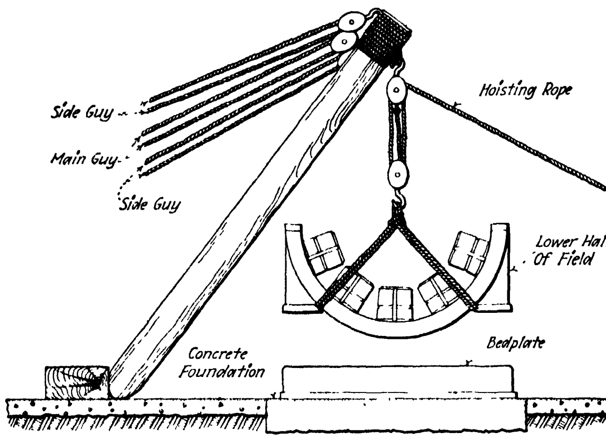


Fig. 174.—Lifting lower half of a field onto a bedplate with a gin pole.

encountered. For discussion of gin poles, see Sec. 32. The lower frame can sometimes be placed on its support by raising it with a stationary hoist, swinging it onto another (Figs. 127

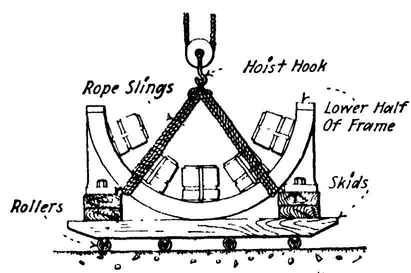


Fig. 175.—A method of fastening a lower section of a frame to a crane or hoist hook. Before the frame is raised, it should be unbolted from the skids.

and 128), and then letting it down into place with the second hoist.

232. Note.—After The Frame Has Been Placed In Its Approximate Position, it is accurately aligned as described in Div. 4.

233. The Lower Half Of The Field Can Be Rolled Into Position when no hoist or crane is available. Planks are placed across the bedplate at the place where the frame is to be located (Fig. 176). The machined surfaces of the bedplate, upon which the frame rests, must be protected from scratching by some padding material. The lower half of the frame is rolled

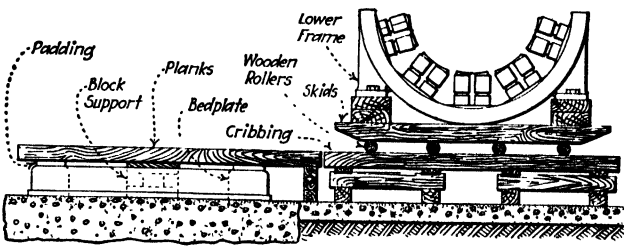


FIG. 176.—Method of rolling lower half of frame onto bedplate.

from a cribbing alongside the bedplate onto the planks which are over the bedplate and into approximately its proper position. The skids and the planks are then removed and the field is lowered with jacks into position on the bedplate. Many frames have a pocket, as at *A*, Fig. 177, through which a timber may be inserted. When no such pocket exists, the

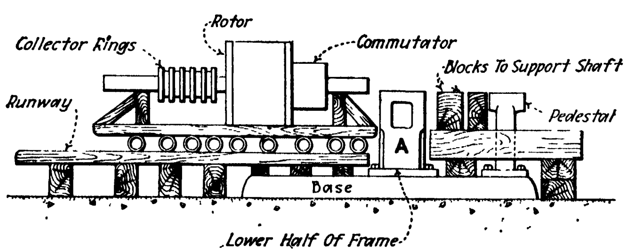


FIG. 177.—Showing the first step of a method of rolling a rotor into position in the bearings. (NORMAN L. REA, *Power*, P. 868, Dec. 25, 1917.)

timber is laid across the field frame and lashed tightly to it with a rope (Fig. 178). By using a jack first under one end and then the other, or by using two jacks one under each end, the frame can be lowered slowly but safely into place. The same method can be employed for placing the lower frame on a soleplate when one is provided.

234. NOTE.—IF THE ROTOR MUST BE ROLLED IN FROM THE SIDE (Fig. 183), as is often the case with engine-type generators, instead of from the end (Fig. 177), the planks should be laid on the base under the position to be occupied by the commutator. By this arrangement when the rotor is rolled into place, it will have to be raised only high enough to clear the commutator. After the rotor is in place, the lower part of the field can be slid in the direction of the shaft into its approximately proper position.

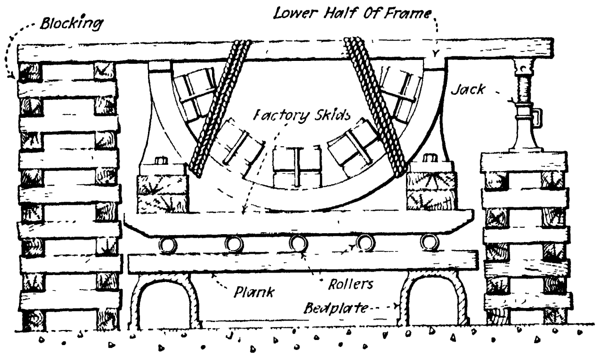


FIG. 178.—Method of letting lower half of frame down on bedplate.

235. NOTE.—WHEN THE MACHINED SURFACE, WHICH SUPPORTS THE FRAME PROJECTS ABOVE THE REST OF THE BEDPLATE, wooden strips of the same thickness as the machined bosses, should be placed between the frame feet and the top of the bedplate. After the armature and shaft are in position, the lower frame can be slid into position.

236. The Rotor Is Placed In The Bearngs after the bearing pedestals have been accurately aligned and fixed in position, as explained in Div. 4, and after the lower half of the frame has been placed on the base. All the bearing pedestals must be placed, bolted, and doweled (and if a removable bridge is provided, it also should be bolted and doweled) before the rotor can be placed in the bearings. The protective coating on the shaft should be removed. The journal should be wiped clean and dry and polished with crocus cloth, if necessary. Any burrs or rough spots on the journal should be removed with a fine file or oilstone. The journal should then be covered with a film of oil. The oil wells and bearings must be thoroughly cleaned of grit and dust. The bearings should be covered with a film of oil. The rotating part can then be lowered

into the bearings. The oil rings should be put in place and adjusted so that they are free to move. Then the oil wells are filled with good oil to the proper level. The bearing caps should be put in place and the bolts screwed down.

237. NOTE.—WHEN IT IS NECESSARY TO LEAVE THE BEARINGS OPEN for a considerable length of time while assembling, it is desirable to cover them with canvas.

238. The Rotor Is Generally Lifted Into The Bearings with a crane or hoist. Rope slings are placed around the shaft in such a manner that they will not contact with the windings or mar that portion of the shaft which rests in the journal. Any roughness at the journal would cut the babbitt of the bearings and produce excessive heating when the machine is in operation. The methods of handling rotors are described in Sec. 7. These same methods can be employed for placing the rotor in position in the bearings.

239. On Some Machines, Such As Rotary Converters, The Rotor Can Be Rolled Into Position From The End.—One method consists of cutting off pieces from the forward ends of the skids, so as to allow the rotor (but not the skids) to pass through the frame (Fig. 177). When the shaft projects out on the far side of the frame, it is supported by blocks (Fig. 180). Then, additional parts of the skids are cut off, and the rotor

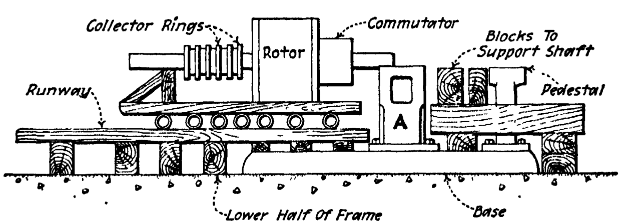


FIG. 179.—Showing the second step of a method of rolling a rotor into position in the bearings. The fore part of the skids are cut off and the armature is supported on the skids.

pushed forward until it is in the proper position. The method as applied to a rotary converter is described in detail in the following explanation.

240. EXPLANATION.—Remove the bearing pedestal at the collector-ring end of the base and the top half of the bearing at the commutator

end (Fig. 177). Roll the armature, with its commutator end first, over the collector-ring end of the base, until the skids touch the field frame. Remove the rollers from under the front part of the skids and rearrange them close together under the remainder of the skids (Fig. 179). Place some padding material and blocks under the armature so that it will be supported on the skids independent of the commutator-end support. Cut off the fore part of the skids (Fig. 179) enough to allow the com-

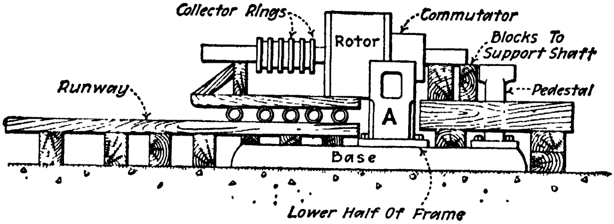


FIG. 180.—Showing the third step of a method of rolling a rotor into position in the bearings. The shaft is resting on the blocks which are placed between the frame and the pedestal.

mutator end of the shaft to be caught on the blocks placed between the frame and the pedestal. Allow the armature to move forward until the shaft projects slightly beyond the commutator-end of the frame.

Carry this projection of the shaft either on a wooden roller or on clean, greased blocks (Fig. 180). A metal roller should not be employed because it will mar the shaft. So arrange the blocking which supports the shaft that sections of it can be removed to provide space for the commutator as the rotor is shifted forward. Saw off a second part of the skids to allow the armature to move forward until the shaft enters the commutator-end bearing, and roll it forward. Then transfer the weight of the rotor to blocking under the collector-ring end of the shaft or to a pad between the field-pole faces and the armature punchings. Heavy cardboard, sheet fiber, or old belting can be used as a pad. Remove the remaining sections of the skids. Set the collector-ring end pedestal into place and raise the armature with a jack under the shaft extension. Remove the pad between the armature and the pole faces or the blocks at the collector-ring end of the shaft, whichever is supporting the rotor, and place the lower half of the bearing lining in position. A method of raising an end of the shaft is shown in Fig. 181.

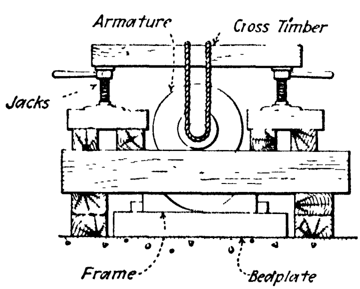


FIG. 181.—Showing a method of lowering or raising a rotor with jackscrews.

241. NOTE.—AN EXPERIENCED MAN WILL HAVE TO CUT OFF ONLY TWO SECTIONS OF SKIDS to place the armature in position. One who has had no experience had better take it easy and saw off the skids in three or four sections instead of two.

242. NOTE.—WHEN AN EXTENSION AND AN OIL DEFLECTOR ARE PROVIDED ON THE SHAFT inside the commutator-end bearing, the blocking must be high enough to carry this projection over the bearing pedestal —or the pedestal must be removed.

243. NOTE.—THE SKIDS MAY BE CONTINUED THROUGH THE LOWER FRAME, if desired. Instead of cutting the skids several times, the runway (Fig. 182) may be built sufficiently high that the skids will clear the fields when the skids are moved through the frame. The rollers under the commutator end of the skids should then be removed and placed

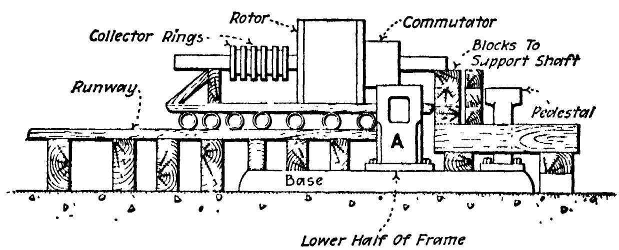


FIG. 182.—Method of rolling a rotor into position in the bearings without cutting the skids.

under the remaining part of the skids. The rotor may then be rolled forward until the commutator ends of the skids project out on the far side of the frame. A runway should be built between the frame and commutator-end pedestal. Rollers, after they have been taken out from the collector-ring end of the skids, can be placed between the skids and this commutator-end runway. The rotor may then be rolled forward on both runways until the skids touch the bearing pedestal; no rollers being employed when the skids pass through the frame. If the skids are as long as the shaft, a piece should be cut from their forward ends so that the shaft will extend through the bearing when the skids almost touch the commutator-end pedestal. The weight of the rotor may then be transferred by means of rope slings to two cross timbers (Fig. 181) each supported by blocks or two jacks. The skids can be removed and the slip-ring-end pedestal and bearing installed. The rotor can then be let down into position with either two or four jacks (Fig. 181).

244. The Rotor May, In Some Cases, Be Rolled Into Position From The Side.—On some machines, especially engine-driven machines with flywheels, it is sometimes impossible to roll the rotor into position from the end (Sec. 239).

Under such conditions the rotor may be rolled into position from the side by the method explained below.

245. EXPLANATION.—The armature shaft with its skids should be jacked up into a position alongside that which it is to occupy in the bearings. The shaft should be raised to such a height that all of it will clear the frame and pedestals as it is shifted over (Fig. 183) into position. Usually, it must be elevated sufficiently that the commutator will clear the top of the lower half of the frame (Sec. 234). Blocking or cribbing must be placed under the skids as they are being raised. Then, the shaft must be removed from its seat on the skids and placed on a runway which is erected over the tops of the bearing pedestals. One or two jacks should be set on a timber which is laid across the skids and a wooden

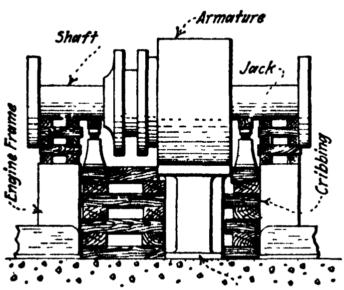


FIG. 183.—Rolling a large rotor into place.

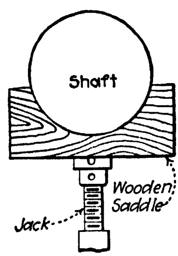


FIG. 184.—Wooden saddle for holding shaft when it is being raised with a jack.

saddle placed between the tops of the jacks and the shaft (Fig. 184). If one jack is employed, it must be placed directly under the center line of the shaft.

As the shaft is raised, small wedges, shaped to fit the shaft and seat, should be placed between the shaft and its seat in the skid frame. One end of the shaft must be elevated at a time, and it is desirable to make short lifts and keep the shaft as nearly level as possible. If four jacks are available, all of them may be used; both ends of the shaft may then be raised simultaneously and no small blocks will be necessary. The shaft must be raised high enough to allow the timbers for the runway to be passed under it. These timbers, one for each end of the shaft, should reach across to, and rest on, blocks laid on top of the bearing pedestals. Small clean blocks should be placed in the bearings and the blocking built up until the runway is practically level.

The rotor can then be rolled from a position beside the machine to one directly over the bearings. In rolling the shaft, it should be maintained parallel to its final position; it is not easy to slide one end ahead, then to

"even" it. The shaft will now be lying on the runway timbers above the bearings. With two jackscrews and a cradle (Fig. 184), the shaft may be raised sufficiently that the runway timber at one end can be removed. Similarly, the timber at the other end may be removed. The shaft should be lowered slowly with the jacks (Fig. 185), the blocks being removed as the shaft descends, until the rotor rests in the bearings. In

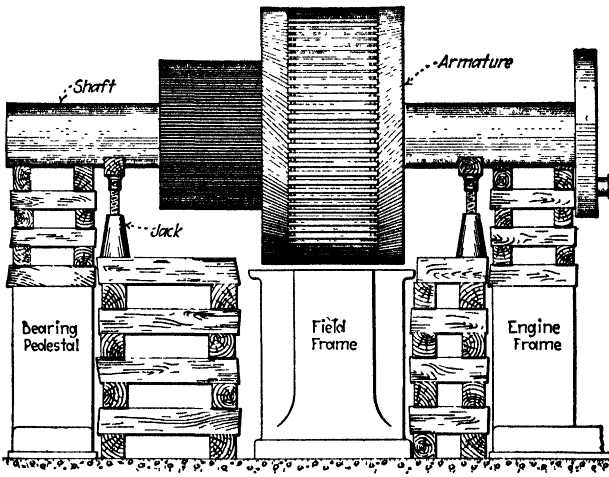


FIG. 185.—Letting armature and shaft down into its position in the bearings.

lowering the shaft let down one end at a time—unless four jacks are employed, in which cases both ends may be lowered simultaneously.

246. NOTE.—IN ROLLING THE SHAFT, IT SHOULD BE PREVENTED FROM MOVING TOO RAPIDLY.—On large machines, this can be accomplished by wrapping several turns of lashing around the shaft or around a crank disk (Fig. 186), if one is provided. One end of the lashing should be attached to the hauling tackle, while the other should be tied to a smaller tackle for holding back.

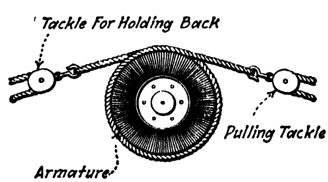


FIG. 186.—One method of holding an armature back as it is rolled forward so that it is always under control.

247. The Erection Of A 150-Kw. Engine-Type, Direct-Current Generator (Figs. 187, 188 and 189) is desciibed in the following material from *Electrical Record* for January 1924. The machine was to be installed on a foundation which had already been erected. The machine had been shipped in three

parts, each of which was mounted on skids. This provides a good example of those cases in which relatively large apparatus must be installed with little available rigging and meager facilities.

248. Explanation.—A timber runway AB (Fig. 187) was constructed which also bridged the opening CD in the foundation. The lower half

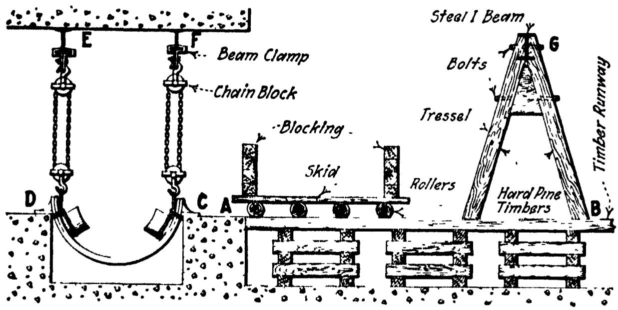


Fig. 187.—Placing the lower half of the field frame.

of the field frame, on its skids, was jacked up and rollers were inserted under the skids, as shown. Then this lower half was rolled to a location, CD, over its final position.

One steel floor beam, F, was in the proper position, for hoisting, but the next floor beam was too far away. Hence, to provide a hoisting runway at the proper position, E, a pair of trestle legs were secured to

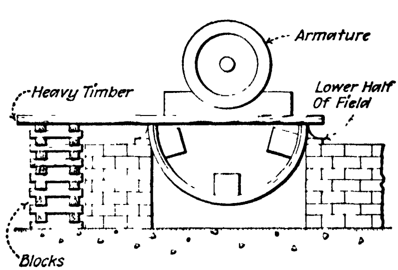


Fig. 188.—Placing the armature.

one end of a 10-in. I-beam G. This G beam was then moved to position E. The other end of G was clamped to another floor beam with heavy, double, beam clamps.

A set of chain blocks was attached to E and one to F and this lower half of the field frame was lifted from the blocking on the skids. The blocking and skids and the runway across CD were not removed. Its flanges were cleaned and the lower half of the field frame was lowered into its

place on the soleplates on the foundation. After this lower half had been aligned and leveled, the bearing pedestals were set loosely on their foundations.

The armature was placed as shown in Fig. 188. A timber runway was arranged, on cribbing, sufficiently high that the armature, on its skids, could be rolled into position. The armature was slung, with manila rope. A spreader (Fig. 6) was employed to avoid the crushing of the winding. The boxing was removed from the armature, its shaft was cleaned, the runway was taken down and the armature was lowered into its bearings.

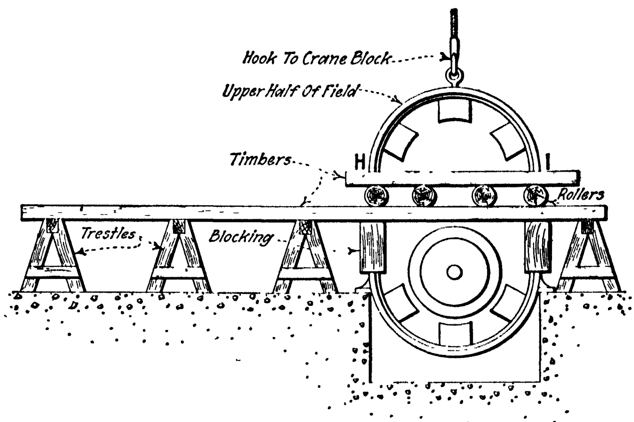


FIG. 189.—Placing the upper half of the field frame.

To place the upper half of the field frame (Fig. 189), trestles and blocking were employed to support the runway. Then this upper half was, on its skids, rolled to the position *HI* over the lower half of the field frame, which was already in position. The upper half was lifted by its eyebolt, the lifting chain block being supported by beams *E* and *F* (Fig. 187). The runway and blocking were removed. Then the frame joints were cleaned. Then this field-frame upper half was lowered into position on the lower half, the dowel pins were inserted and the two halves were bolted together.

249. On Some Large Machines The Rotor Must Be Pressed On The Shaft at the place of installation. For such machines the shaft is turned accurately at the factory to a certain size and the rotor hub is bored out to a size several thousandths of an inch smaller than the shaft. This provision permits a press fit to be made between the amature and the shaft. Before forcing the armature on the shaft, the surfaces which are to be

fitted should be inspected for any rough spots or scratches which they may have received during transportation. Any roughness must be filed down with a fine file and smoothed with fine emery cloth. The key should then be inserted in the shaft; it should be inspected to insure that it has a good bearing on its sides and that its top has a clearance of about $\frac{1}{32}$ in. The outside surface of the shaft and the interior surface of the hub, that contact with each other during the fitting process, should be painted with a mixture of white lead and engine oil to prevent any cutting of the shaft. Any roughness on the shaft may cut the bearings and cause heating during operation. The rotor may then be pressed on the shaft.

250. Large Rotors Should Be Pressed On Their Shafts With A Hydraulic Press.—The forces required to place the armature will vary so greatly with the diameter, temperature, condition of the surfaces, and quality of the metals that it is impossible to estimate its value with any accuracy. However, a force of between 100 to 200 tons is generally required.

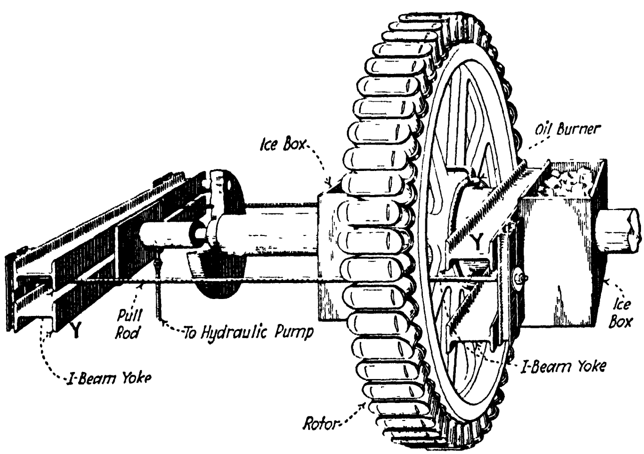


FIG. 190.—Equipment for pressing on a rotor that had stuck on the shaft. (KENNETH A. REED, *Power*, p. 768, November 25, Dec. 2–9, 1919.)

251. NOTE.—WHEN A HYDRAULIC PRESS IS NOT AVAILABLE, the rotor can be forced on the shaft by the following method: Make two I-beam yokes, *Y* (Fig. 190), and place one of these across the rear of the rotor and one at the end of the shaft. Then draw the rotor into place by means of two bolts which pass through the yokes and armature spider,

close to the hub. The bolts should be tightened evenly, otherwise the hub may twist and bind on the shaft. The operation, when once started, should be carried continuously to completion, because, if the rotor is permitted to set several hours when only part way on the shaft, it will require from 25 to 50 per cent more force, than was previously used, to start it again.

252. NOTE.—A LARGE ROTOR WHICH HAS NOT BEEN PRESSED ON ITS SHAFT should be supported, whenever possible, on the spokes of the spider. This can be done by passing heavy timbers through the spider and blocking up to them at each end. When such support is impossible, the rotor may be placed in a cradle which is cut out of heavy timber to fit it, and which is lined with excelsior, waste, or other soft materials. Such an arrangement will distribute the weight evenly over a large area of the core. The cradle should be made narrower than the core to prevent any injury to the winding.

253. Heating A Large Rotor Or Flywheel Before It is Pressed On Its Shaft, eliminates a considerable amount of the labor and expense of pressing them together. By uniformly heating, as in an oven box (Fig. 191), the rotor or flywheel, its bore is enlarged by the expansion caused by the temperature increase. In most installations, a sufficient expansion may be thus obtained to permit the shaft to be inserted into the rotor or flywheel in its proper position without employing any pressure. Hydraulic jacks or some other press equipment should be kept in readiness for instant use in case the rotor or flywheel does not slide readily into place on its shaft. In probably ninety-nine out of one-hundred jobs this pressing equipment will not be needed, but in the one-hundredth job, serious trouble may be encountered if it is not ready for use. The important factor in this work is speed. The rotor must be brought to its final position on the shaft before it has had time to cool to the normal temperature.

254. NOTE.—THE HEATING OF THE ROTOR MAY BE ACCOMPLISHED IN SEVERAL WAYS but it is essential that it be uniform and fairly slow. Low-pressure steam injected in the oven box (Fig. 192), hot-air supplied by either a hot-air transformer drier or a hot-air furnace, the air being taken from the bottom of the oven and discharged back into the top, or any electric heater may be employed to heat the rotor. Low-pressure steam admitted into the oven (Fig. 192) gives the most uniform heat distribution. The coldest part of the rotor will condense the largest amount of steam and consequently will absorb the most heat. In this manner, the heating tends to equalize itself but the condensation formed

makes a mess which may be objectionable and the temperature is limited to about 100°C. This method cannot be employed for a wound armature or for a field with the poles in place as the moisture will injure the coils. The injection of hot-air from a drier gives good results but usually it is

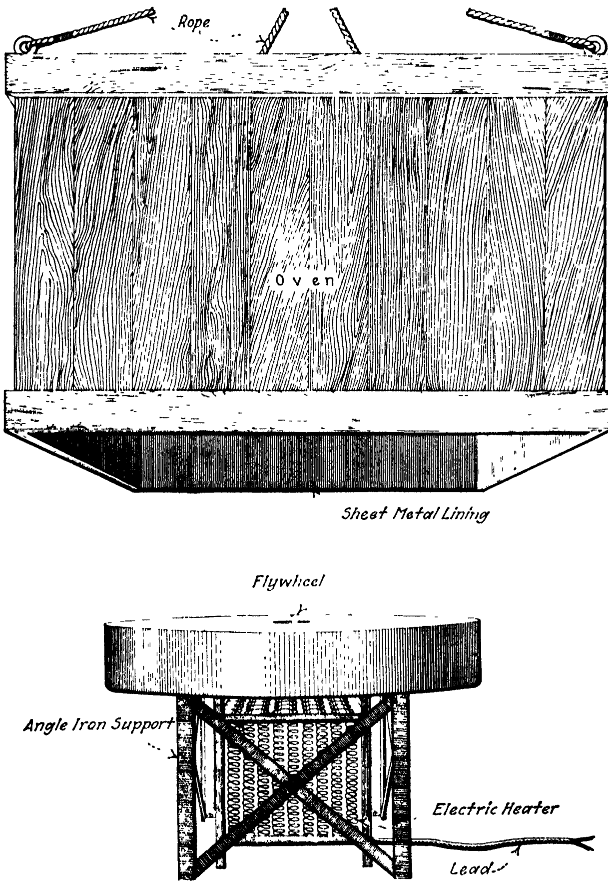


FIG. 191.—Flywheel and heater ready for oven to be lowered over them.

more desirable to heat the air around the rotor directly with an electric heater. The latter method is the one most commonly employed. The heater and the oven should be so arranged that the air will circulate around the piece and distribute the heating (Fig. 191). When a wound rotor or assembled field is heated, a little ventilation should be allowed for carrying off any moisture that may be in the windings.

255. NOTE.—GAS OR OIL FLAMES ARE NOT DESIRABLE FOR HEATING THE ROTOR.—These flames are too hot and the heat is generally localized. Such heating may cause serious distortion or even breakage of the part. The use of such fire often decreases instead of increases the bore of the hub. This is caused by the rim of the rotor not heating up as fast as the spokes and hub, which necessitates the expansion taking place inwardly instead of outwardly.

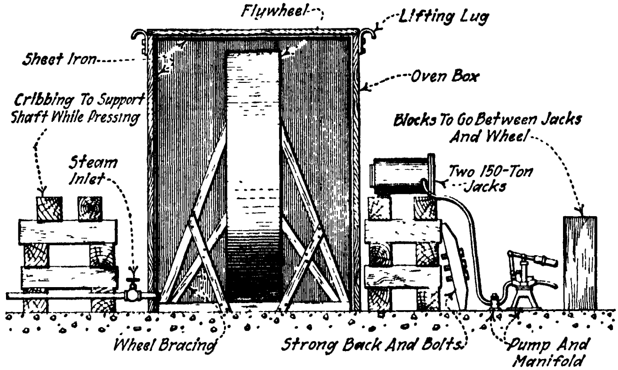


FIG. 192.—Arrangement for heating rotor in vertical position before pushing shaft into place.

256. A General Method Of Heating A Flywheel Or Rotor With An Electric Heater is illustrated in Fig. 191 and described herein.[1] This method may be modified to comply with the local conditions encountered. The flywheel, or part to be heated, is supported several feet above the floor on an angle-iron framework, inside of which is placed an electric heater (Fig. 191). Another method of support is shown in Fig. 193. The heater can be made of iron wire supported on porcelain knobs fastened to iron pipes or to iron rods (Fig. 193). Any resistance grid may be used instead. After the heater and flywheel are in place, an oven is lowered over them with a crane. The oven consists of a bottomless box that has a small hatch in the center of its top and should be large enough to fit over the flywheel. The box is made of wood and lined with sheet iron which is separated from the wood by battens so as to provide an air space between the iron and wood. Bright

[1] From an article by N. L. REA in *Power* Mar. 13, 1922, p. 392.

galvanized iron or tin is better than black iron because it reflects more heat and decreases the amount of heat lost by radiation. When the oven is in place, the heater is turned on and the rotor is heated until the bore is expanded to the proper size, which is determined by measurement.

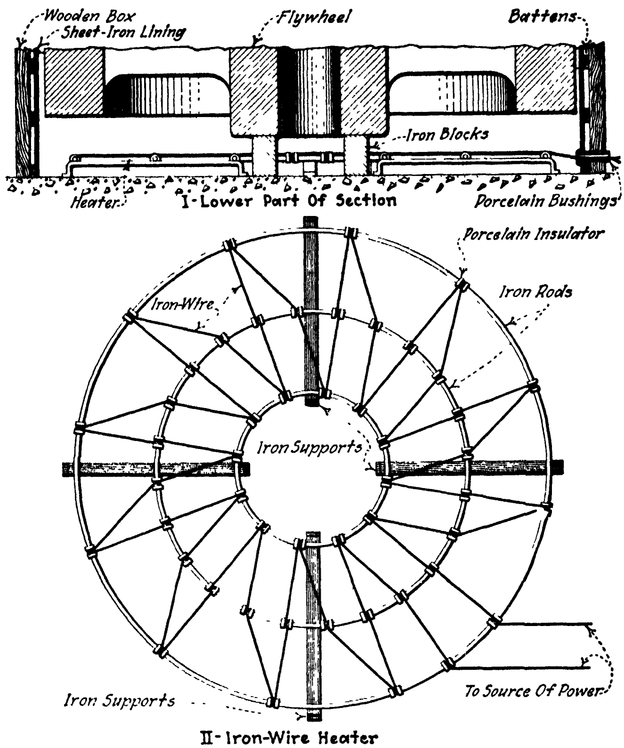


Fig. 193.—Arrangement of the flywheel support and iron wire heater in the oven for heating the flywheel.

257. Note.—The Expansion Of The Bore May Be Measured with a pin gage (Fig. 264), and "feelers" or with an inside micrometer. When the pin-gage method is employed, the gage should be set to the diameter of the bore when the rotor is cold. Then, the amount of expansion, when the rotor is heated, is measured with the "feelers" (thickness gage) between one pin and the inside of the bore. Sometimes the measurement can be made through the hatch in the top of the oven —but usually the whole oven must be lifted. The measuring must be

done rapidly because the gage or micrometer will soon become heated and give an incorrect reading. The gage should be kept in a cool place between readings.

258. NOTE.—HEATING WITH AN ELECTRIC HEATER IS VERY CONVENIENT.—It usually requires about 24 hr. of heating to obtain the proper expansion. The heaters range from 5 to 30 kw. although 10 or 12 kw. should be sufficient for the largest part, if proper care is taken to make the oven box tight. It seldom pays to heat above 200°F. because as the temperature increases it becomes more difficult to heat the part through and through to the same temperature and also the heat losses increase. The bores usually expand about 0.0009 in. per inch of diameter for each 100°C. or 180°F. rise in temperature.

259. NOTE.—EXAMPLES OF ELECTRICAL ENERGY REQUIRED FOR HEATING ROTORS.—On one installation, the heater took about 125 amp. at 220-volts. The oven employed was 5½ ft. square by 4 ft. high. After heating the assembly for 24 hr., the oven reached a temperature of 180°C. and the bore (which was 24 in. in dia.) of the rotor expanded 40 mils. On another installation, seven 750-watt lamps (one hung between each pair of spokes) were used to heat a large rotor. The rotor and lamps were covered with several tarpaulins. The bore was expanded 8 mils. after heating it for 24 hrs.

259(*a*). While The Rotor Is Being Heated, the shaft is cleaned, smoothed, and coated with white lead thinned to the consistency of paint with a mineral-base machine oil. It is set vertically on its coupling face in some convenient place, as a spare generator pit, braced securely, and provided with stops to prevent the flywheel from dropping too far down (Fig. 194). A pressing rig (about as shown in Fig. 194), is collected so as to be in readiness in case of trouble. In Fig. 194, the pressing rig comprises two 150-ton hydraulic jacks with a pump and manifold. When the bore of the hub has been expanded sufficiently, as determined by measurement, the rotor is quickly dropped over the shaft into position. Usually it will not be necessary to use the pressing rig but it should always be in readiness.

260. NOTE.—WHEN LARGE CRANES ARE NOT AVAILABLE, IT MAY BE DESIRABLE TO BLOCK THE ROTOR of a horizontal machine on edge (Fig. 192). The oven is then placed over the rotor and arrangements made to bring the shaft to the rotor. The shaft is inserted part way in the flywheel and supported on blocking. The rigging grip on the shaft can then be changed and the shaft pulled up into position in the flywheel.

261. Note.—Under Some Conditions It May Be Desirable To Drop The Shaft Through The Rotor.—This can be accomplished by building the oven over a hole in the power-house floor. The hole in the power-house floor should be closed and a trapdoor provided in the cover large enough to admit the shaft. When the rotor has expanded, the shaft can be let down through the oven, rotor, and the bottom trapdoor.

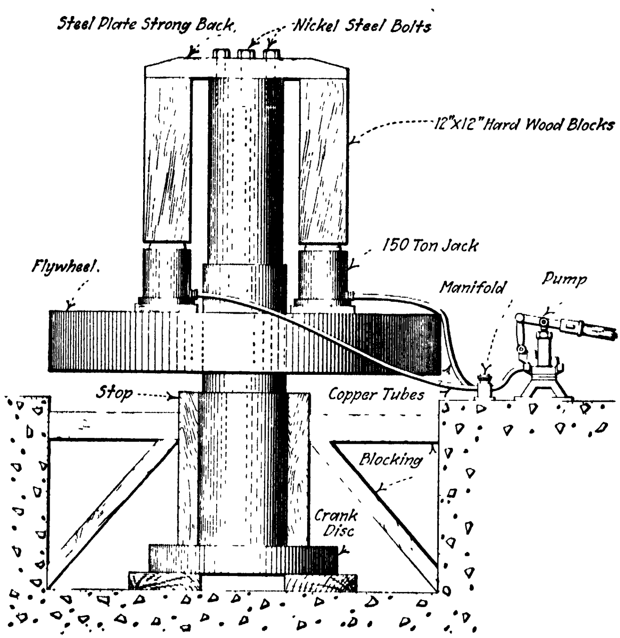


Fig. 194.—Hydraulic jack arrangement for pressing on rotor in case it should set before reaching correct position. (N. L. Rea, *Power*, P. 393, March 13, 1923.)

262. When The Rotor Is Composed Of Sections, each section should be separately heated and placed in position on the shaft. Each section that has been placed should be allowed to cool to the normal temperature before the next section is set in position. The sections, as they cool, contract along the shaft as well as at right angles to it. Hence, if two hot sections are placed together on the shaft, their outer surfaces would cool first and bind on the shaft. Then, as the inner parts cooled, the hubs would contract longitudinally and

the sections would slightly separate. However, when a hot section is placed beside a cold one, that part of it which is next to the cold section will cool and grip the shaft first. Then, the contraction will be toward the section already in place and the sections will pull together tightly. The two sections must be so placed that the keyways for the pole pieces are in line and will remain so when cold. Short dummy keys should be placed in two diametrically opposite slots that are midway between the shaft keys. If the slots are not so aligned, a very small clearance on the shaft keys may cause the pole keyways to be out of line.

263. NOTE.—ON SOME ROTORS THE SECTIONS ARE RABBETED TOGETHER as shown in Fig. 195. The sections are often designed to be pressed on cold; but the erector may decide to save time by heating the sections. In such cases, the recess may be in the inside hub of the first section. The first section can be placed readily. When the second section is heated, the projection expands also and becomes too large to fit in the recess of the first part. The projection should, under those conditions, be chipped off or filed down to give the clearance needed. The rabbet joint is not necessary in assembling the rotor as the shaft and keys hold the sections in place.

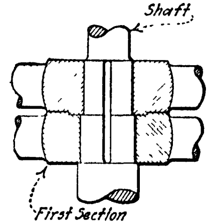


FIG. 195.—Rabbeted joint with the recess in first section.

264. A Rotor May Stick While It Is Being Pressed On A Shaft so that it cannot be moved with the hydraulic press available. Such a condition always gives considerable trouble. If sticking does occur and the rotor can be forced back off of the shaft this should be done. It can then be heated, as described in Sec. 254, and pressed on the shaft while it is hot. When the rotor cannot be pushed off the shaft, or when it is not desirable to do so, the method described below may be pursued.

265. EXPLANATION.—From an article by Kenneth A. Reed, Power, Nov. 25, 1919, p. 768. In Figs. 190 and 196 an arrangement is shown whereby a rotor, which had stuck on a shaft, was pressed into place with the same hydraulic pump that would not move it in the ordinary manner. The rotor was 14 ft. in diameter and had a hub 18 in. long, one-half of which was bored to approximately 26 in. in diameter and the other half to 26¼ in. The shaft was 0.025 in. larger in diameter than the bore of the hub. With the key and keyway carefully lined, the rotor was pressed onto the shaft with a 250-ton hydraulic press. The rotor

moved for 3 in. and then one of the I-beams broke. After substituting larger I-beams (20-in. extra heavy), the rotor would not move when a force of 260 tons was exerted by the press.

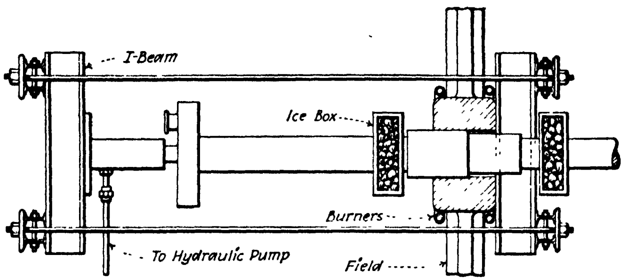


FIG. 196.—Plan of the arrangement shown in Fig. 190.

The equipment of Fig. 190 was then arranged. The oil burners were made of ¾-in. pipe with 1/16-in. holes drilled 3 in. apart on their inner peripherys. The iceboxes were placed around the shaft but not permitted to touch the rotor. The burners were piped to an oil tank

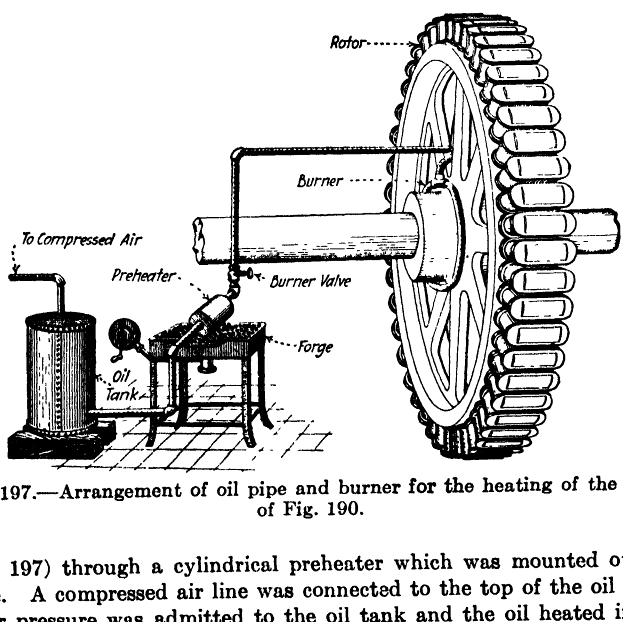


FIG. 197.—Arrangement of oil pipe and burner for the heating of the rotor of Fig. 190.

(Fig. 197) through a cylindrical preheater which was mounted over a forge. A compressed air line was connected to the top of the oil tank.

Air pressure was admitted to the oil tank and the oil heated in the preheater for several minutes. The burner valve was opened and a

torch was applied to the burners. The press pump was started again and, about 10 minutes after the burners were lighted, the rotor began to move under a force of 175 tons. The force then dropped to 75 tons and it remained at from 75 to 90 tons until the rotor was in place. When employing this method care should be taken not to allow the oil flame to become too hot. The flame should be just hot enough to keep the rotor at normal temperature while the ice cools the shaft below normal. The winding should be protected from the flames.

266. After The Rotor Is In Position The Upper Half Of The Frame can be placed on the lower half and the two bolted together. Before setting the upper part on the lower one, the contract surfaces on both should be cleaned. The adjacent parts of the two halves should be similarly marked by their manufacturer so that the two sections can be properly placed together. The upper half of the frame may be lifted to its place with a traveling crane, an A-frame (Fig. 22), a gin pole, or other hoisting apparatus in a manner similar to that employed for the lower frame (Sec. 231). The top part of the frame is usually provided with one or two eyes for attaching a crane or hoist hook. When no eyes are provided, slings can be placed around the top of the frame for attaching the crane or hoist hook. Care must be taken, however, not to injure the windings. On alternating-current machines, holes are usually provided in the armature frame through which the slings may be passed. On field frames, the slings can usually be placed between the field poles.

267. NOTE.—THE TOP HALF OF THE FRAME CAN BE ROLLED INTO POSITION when no hoisting equipment is available. The method is illustrated in Fig. 198. The top half of the frame is jacked up over a crib until it can be rolled onto a runway, which has been erected at the same height as the top of the lower half of the frame. The upper part is rolled onto the runway into the position shown in Fig. 198. Then it is raised by the jack and beam arrangement so as to allow the removal of the skids. Next, it is lowered slowly onto four or five small-diameter wooden rollers. On these rollers it is rolled into a position over the lower part. Another lift is made as before, the rollers are removed, and the upper half is let down onto the lower half. If the field coils interfere, so that the joint bolts will not enter the holes when the two parts are together, the bolts must be inserted in the upper part before it is lowered into place. On an engine-type generator which is provided with a fly-wheel, the beam can be supported on the flywheel instead of on blocks

which rest on the bearing. Obviously, if the flywheel is so used it must be blocked to prevent its turning and must be wedged against the top beam. The same method, with perhaps some slight modifications, can be employed on machines which are supported on soleplates or rails.

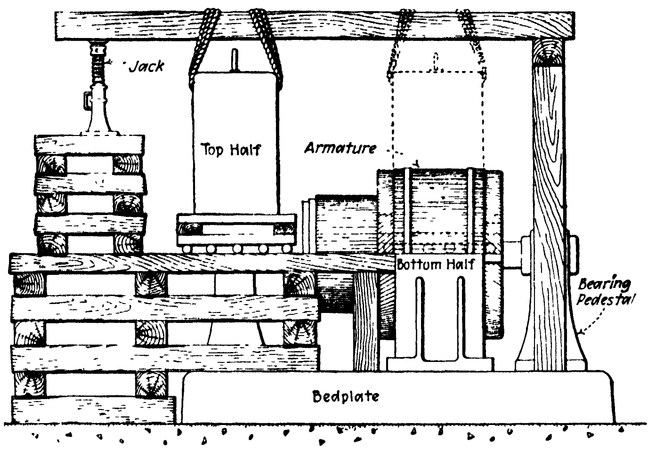


Fig. 198.—Rolling upper half of frame onto the lower half.

268. On Motor Generator And Frequency Converter Sets, The Motor Frame is often made in one piece. Such sets are sometimes provided with a removable bridge on the motor end. With this construction the motor frame can be slid into place from the end, by removing the outer bearing and the removable bridge. On two-bearing machines, the shaft must be supported at the center before the outer bearing is removed.

269. Note.—When No Removable Bridge Is Provided or when two frames are each made in a single piece, then the rotor must be threaded into place in the frames. This can be done in a manner similar to that employed for placing a rotor in a synchronous motor or alternator which has a single-piece frame (Sec. 270).

270. On A Synchronous Motor Or Alternator Which Has A One-Piece Stator, the rotor can usually be threaded through the stator in a manner illustrated in Figs. 199 and 200. Two slings are placed around the shaft close to the rotor and attached to a crane hook. The rotor is let down beside the stator and at the same time the short end of the shaft is threaded through

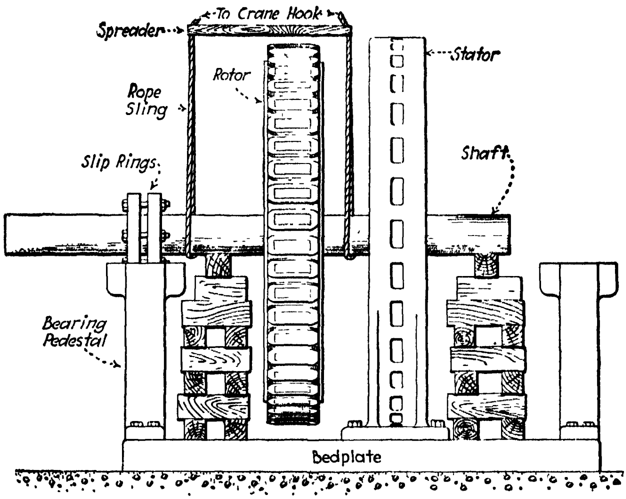


FIG. 199.—Showing first step in a method of threading the rotor of a synchronous motor through its stator.

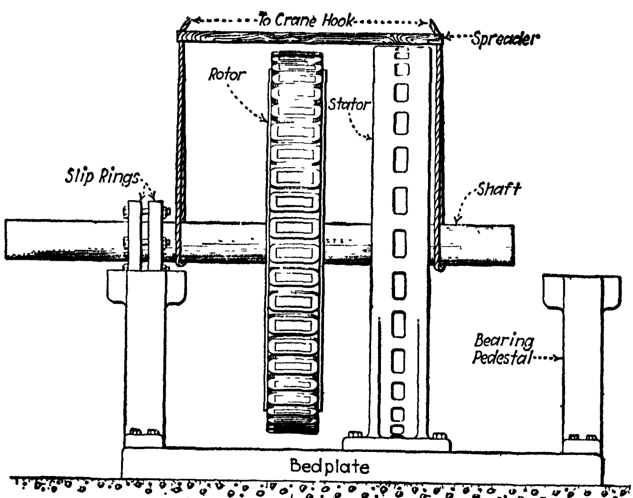


FIG. 200.—Showing second step in a method of threading the rotor of a synchronous motor through its stator.

the stator, until the rotor is in approximately the position shown in Fig. 199. Blocks are placed under both ends of the shaft to support it (Fig. 199). The slings are then removed and replaced on the shaft in the position shown in Fig. 200. The shaft is raised from the block supports, and moved over and lowered simultaneously into its position in the bearings. During the procedure, care should be taken that the armature coils are not damaged by the shaft or rotor.

271. Note.—On Some Machines, The Rotor Cannot Be Threaded into the stator while the bearing pedestals and stator are in place. With some such machines, the rotor may be inserted if the stator frame is moved to one end of the machine For such machines the stator should be set near one end of the machine and the rotor and shaft let down into the bearings. The rotor may sometimes, if the stator is sufficiently close to the bearing pedestal, be lowered into position with only one grip of the slings. Afterwards the stator can be slid into place. In other installations, one of the bearing pedestals must be removed before the rotor can be inserted. The method to be employed on any machine should be decided before the erection is started, so as to eliminate any unnecessary waste of time and labor.

272. After The Rotor And Frame Have Been Placed In Approximate Position, The Frames Must Be Aligned with the rotors. The air gap between the frame and the rotating part should be made equal all around and the rotating-part laminations should be placed exactly opposite the stationary-part laminations by one of the methods described in Sec. 421. If an exciter is provided, it should be set and connected with the main unit. Place the brush rigging in the proper position. Connect up all the field and armature leads.

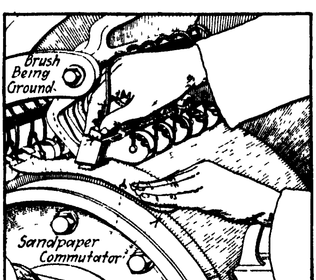


Fig. 201.—Grinding brushes with sandpaper. (Westinghouse Electric & Mfg. Co. *Inst. Bk. No.* 5107-*A*).

273. Insert The Brushes In Their Holders And Grind Them In by holding sandpaper under each brush while pressing it against the commutator (Fig. 201). The sandpaper should cut the brush only on the forward stroke and as it passes

under the brush in the direction of normal rotation. Copper-plated brushes should have the copper sheath edges slightly beveled to prevent them from scratching the commutator. Stagger the brushes over the entire width of the collector rings or commutator to prevent the formation of grooves therein. Also, adjust the brushes so that they move freely in the holders and are held under an equal pressure of about 2 lb. per square inch. Graphite brushes should be run at lower pressures; sometimes at as low as 1 lb. per square inch. Alternating-current brushes should be run at from 3 to 3½ lb. per square inch.

274. NOTE.—WHEN THE EXCITER IS DIRECT-CONNECTED AND HAS A SEPARATE SHAFT bolted to the main shaft, it is important that the exciter bearing be accurately aligned with the main bearings and rigidly supported. If the two shafts are not accurately aligned, the small shaft may be fractured near the coupling end.

275. NOTE.—LARGE MACHINES ARE PROVIDED WITH OIL PUMPS.—In installing the oil pumps, and the pipe lines to the pumps, especial care must be taken that no dirt or grit is allowed to remain in the oil system. Each length of pipe should be tapped with a hammer before it is connected in the oil line to remove any foreign material that might be lodged in it. The oil tanks that are employed, the oil wells in the bearing pedestals, and any other places in the system where grit and dirt might settle, should be cleaned thoroughly before they are connected in the system. Improper lubrication is the cause of most of the troubles of large machines.

276. The Brush Arms And Brushholders on direct-current machines must be correctly spaced and located. They are usually correctly adjusted at the factory. The rocker ring is doweled to the frame, or some other method is provided whereby the relationship between the frame and the brushes that was established at the factory can be duplicated at the installations. These adjustments should always be checked before the machine is put in service because the parts may be displaced through disassembly or by rough handling during transportation. The brushholder arms should be parallel to the commutator bars and the brushholders should have a clearance about ⅛ in. between the bottom of the holder and the commutator. The relative spacing of the brush arms

around the commutator, determined from the edges of the brushes, should be uniform.

277. The Spacing Of The Brushes Can Be Checked by tightly stretching a narrow strip of paper around the whole circumference of the commutator under the brushholders and tieing it in place. The paper must be smooth and parallel with the edge of the commutator at all points. The lapping point of the paper is marked; the paper removed and spread out on a flat surface. The length of the circumference marked on it is then divided into exactly equal sections, the number of sections being equal to the number of poles. The strip is replaced on the commutator and the arms adjusted so that the edges of the brushes on the different arms just touch the marks on the paper. The variation in spacing should not be greater than $\frac{1}{16}$ in.

278. Note.—The Running Position Of The Brushes Must Also Be Determined.—On non-commutating-pole machines, the brushes are set ahead for generators and behind for motors, taken in the direction of rotation from the no-load neutral. This position is found by trial. On commutating-pole machines the brush position should be accurately fixed at the no-load neutral and should not be changed, except for paralleling when it may be changed slightly. Most machines have the relative position between the rocker ring (or brushholder studs, whichever is employed) and the frame definitely determined, usually by means of dowel pins. This should be checked by the methods described in the preceding section.

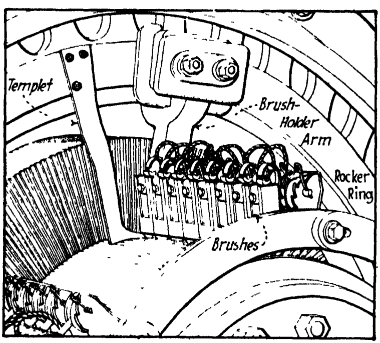


Fig. 202.—Templet in position for setting brushholders. The brushes are in the proper position when they are in contact with the tip of the short leg of the templet. (Westinghouse Electric & Mfg. Co. *Instruction Book No.* 5107-*A*.)

It is just as important to fix the relative location of the brushholders and the rocker ring (or stud). This is accomplished on some machines by bolting the brushholder rigidly to fixed brush brackets and taking up the wear by moving the brushholders radially on the brush brackets. This does not change the position of the brushes on the commutator. On other machines a templet is provided (Fig. 202) which can

be bolted on the rocker ring when the machine is not running. The brushes of one arm can be located with reference to the templet. The templet must be removed before the machine is started.

When the position of one set of brushes has been fixed, the others are uniformly spaced from this set by the paper method described in Sec. 277. Other types of templets and trams are provided by different manufacturers. On some General-Electric machines, the neutral may be determined from factory marks on the armature slots and commutating poles (Fig. 203). With the armature in such a position that the two slots which are painted red are directly under the center lines of two commutating poles, the brushes of the nearest set should be placed directly over the center bar of the marked group of commutator bars.

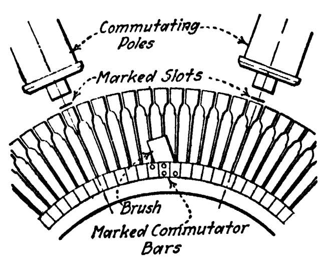


FIG. 203.—Method of setting brushes of a commutating-pole machine when the slots and commutator bars are marked. (GENERAL ELECTRIC CO., *Inst. Bk. No.* 82501-*A*.)

279. NOTE.—WHEN IT IS NECESSARY TO CHECK THE LOCATION OF THE NEUTRAL POINT on the commutator of a commutating-pole machine either the "kick-neutral" or "running-neutral" methods may be employed. The running-neutral method is the more accurate and also the more frequently used.

280. NOTE.—THE KICK-NEUTRAL METHOD is based on the fact that the opening of the field circuit of a direct-current machine induces a voltage in the armature coils. When the brushes are in the neutral position, the resultant voltage so generated is zero. To save time, set the brushes as close as possible to the mechanical-neutral position. On commutating-pole machines, this position is determined by setting an armature slot directly under the center line of a commutating pole and then moving the rocker arm until one set of brushes covers the commutator bars that are connected to the conductors in the slot. Then the brushes are raised. In each arm is inserted one brush, whose face is tapered so that it will touch only one commutator bar. The shunt field is separately excited and a quick-break switch is provided in the circuit. With a low-reading voltmeter (preferably one with 0.5-, 1.5-, and 15-volt scales) connected to the brushes in two adjacent sets, the momentary deflection of its needle is noted when the field is opened and closed. The rocker ring should be shifted until no deflection is obtained.

281. NOTE.—THE RUNNING-NEUTRAL METHOD is based on the fact that when the brushes are in the correct position no active electromotive force will be generated by the commutating-pole flux when the machine is running on open circuit with the commutating windings separately excited. The tapered brushes are inserted one in each arm as in the previous method except that the faces of the brushes must be wide enough

to bridge one mica segment but not more than two commutator segments. The brush faces must also be ground for good contact. The separately excited shunt-field circuit should be provided with a reversing switch and the commutating-pole winding should be excited at from 2 to 4 per cent of its normal current. The commutating-pole circuit is disconnected from the armature and the armature open-circuited. A low-reading voltmeter, as suggested in the preceding method, is connected across brushes in sets of opposite polarity.

The machine is brought up to normal speed and the main field demagnetized, by exciting it for an instant in the reverse direction until no deflection is obtained on the lowest scale of the voltmeter. Now, when the commutating-pole windings are excited, any deflection obtained will be due to their flux alone. The commutating-pole current is now raised to 4 per cent of its normal value and the brush location thus obtained is checked against the position similarly obtained with the 2 per cent current. If no difference is found, the current in the commutating-pole winding is reversed. The residual magnetism of the main poles must be checked from time to time. Since, in this method, the machine is running, errors due to a brush resting on mica only or to brush resistance are eliminated entirely.

282. The Erection Of Assembled Transformers (**Non-Rotational Electrical Machines**) is comparatively simple. Most of the transformers are shipped completely assembled ready to install. A transformer so shipped need only be set in its proper position and then inspected for moisture, damage to coils, and presence of foreign materials. Placing an assembled transformer in position is not very difficult. Each is provided with eyes or lugs for lifting the complete transformer with a crane or hoist. When lifting facilities are not available, it may be rolled into position (Sec. 292). The important point in the erection of any transformer is to prevent the formation of moisture or the accumulation of dirt and foreign material inside of the transformer case. Moisture and other foreign substances in the insulating oil have a very great detrimental effect on its dielectric strength. Large foreign substances such as tools, may produce short-circuits in the windings and cause burnouts or breakdowns.

283. The Oil-Immersed Transformers Are Usually Shipped filled with oil. However, those of capacities below 50 kva. are often shipped dry with the oil sent separately in drums. In a very few cases, it is necessary to ship a large transformer completely assembled, less its oil, and lying on its side. In these

cases, internal blocking is necessary. All the blocking must be removed before the transformer is put into service. On account of insufficient railway clearances, it is sometimes necessary to remove the cover bushings and send them separately. The erection of these transformers will be described with that for the assembled transformers.

284. NOTE.—AIR-BLAST TRANSFORMERS, although of somewhat different construction from those of the oil-immersed type, are erected in a similar manner. The general methods described and the principles outlined in the following sections can be employed. No special methods for their erection will be given.

285. Small Assembled Transformers Can Be Lifted Into Place by any of the methods employed for lifting small motors onto foundations or platforms. Those of capacities below 50 kva. are usually provided with hanger irons for pole or wall mounting (Fig. 204). The larger ones have suitable bases for mounting on a small platform or on the floor. Each

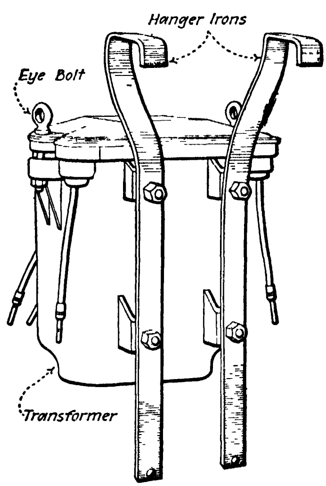


FIG. 204.—Small transformer with hanger irons for pole mounting. (ALLIS-CHALMERS MFG. CO., Bull. No. 1088.)

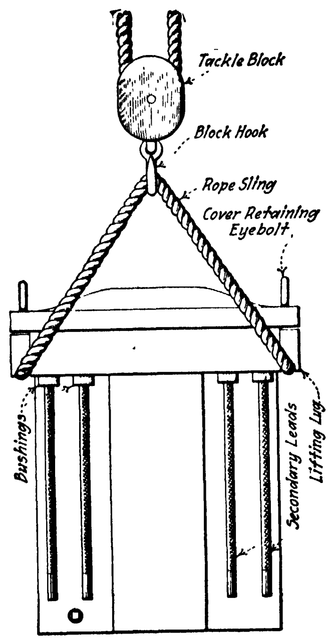


FIG. 205.—Front view of small transformer which is provided with lifting lugs. (GENERAL ELECTRIC CO., *Inst. Bk. No.* 85102-*C*.)

of the transformers is provided with several eyes on its top for lifting. Usually, it is raised into place with a hoist which is fastened to the transformer with a sling slipped through the eyes. Some of the transformers have lifting lugs cast or welded on the sides of their cases (Fig. 205). When these are provided, the lifting tackle should be attached to them instead of to the cover retaining eyebolts.

286. NOTE.—THE TRANSFORMER SHOULD BE INSPECTED FOR INDICATIONS OF MOISTURE OR MILDEW before it is connected. This is necessary although each transformer is inspected in the factory, because accident and condensation of moisture from the atmosphere may occur during shipment and storage. The inspection is made from the top by removing the cover. Moisture can be detected by signs of rust or sweating on the cover, terminal board, tank, core clamp, and core (Fig. 206). Mildew may form on pressboard or other insulation. If moisture or mildew is detected, the transformer should be dried out in a drying oven for a few hours. The temperature of the oven should not exceed 85°C. A tray filled with calcium chloride set in the oven will greatly facilitate the drying process. About 5 lb. of chloride per 100-kva. transformer is required Unslacked lime may also be used. When the transformer cannot be placed in an oven, it may be dried out by short-circuiting one winding and by applying such an alternating current to the other winding as will heat them both to a temperature of 70°C. The current required to give this temperature will usually vary from one-fifth to one-third that of normal full load.

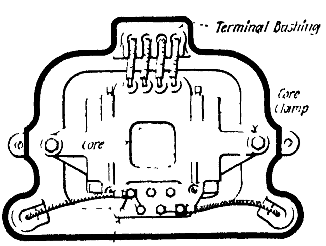


FIG. 206.—Interior of a central station type transformer. (WAGNER ELECTRIC CO., St. Louis.)

287. The Small Transformers Usually Must Be Filled With Oil.—A special oil is used and this is generally sent, in a separate drum or drums, with the transformer. Care should be taken in storing the drums that no moisture will enter them (Sec. 44). On small transformers the oil level is usually plainly marked on the inside of the case. It is important that the surface of the oil be at the level indicated. This mark is for oil, in General Electric Company transformers, at an approximate temperature of 25°C. When pouring the oil into the transformer, it should be strained through two or

more thicknesses of muslin or other closely woven cotton *cloth. The cloths should be renewed as sediment accumulates* on them. Metal hose is preferred to rubber hose for transferring the oil, because the sulphur dissolved from the rubber by the oil may attack the windings. When outdoor installations are made on stormy days, the oil should be put in the case when the transformer is indoors, to avoid the danger of moisture getting into the transformer while the cover is off.

288. Note.—The Oil Should Be Inspected Before It Is Put In Service, because it may take up moisture during transportation. The most reliable test is that of dielectric strength made with an oil-testing outfit. When a testing outfit is not available, a rough indication of moisture can be obtained by heating, very rapidly, a small amount of oil to slightly over 100°C. in a dry saucer. A crackling noise will indicate moisture in the oil. The test sample should be taken from the bottom of the transformer tank after it has stood for at least 24 hr., to allow any water to settle. The standard dielectric strength of oil when shipped is at least 22 kv. with 1-in. discs spaced 0.1 in. apart or 40 kv. with ½-in. discs spaced 0.2 in. apart. No new oil of less than this dielectric strength should be put in a transformer.

289. The Erection Of A Large Transformer Shipped Assembled And Filled With Oil consists in setting the transformer in place and inspecting it for damage and condensation of moisture. The transformer should be set on a good level floor which is strong enough to support its weight. It is usually lifted into place with a crane hook which is fastened by means of slings to the eyenuts or lugs provided for lifting the complete transformer. When lifting a wide transformer, it is desirable to hold the slings apart by means of a spreader or lifting beam (Fig. 209) to prevent bending of the lifting rods or other parts of the structure.

290. Note.—In Lifting Large Transformers, Be Careful To Use The Correct Eyes Or Lugs.—Transformers of the "cover-lifter" type (Figs. 207 and 209), usually those in oval tanks, are lifted complete by eyenuts on the suspension rods extending through the cover. The same eyenuts are employed for lifting the core and coils (Sec. 305). Most of the transformers in round or square tanks are lifted complete by means of lugs riveted or cast on the tank. These transformers may also have small eyebolts in the cover, but these are for lifting the cover only and should not be used for raising the complete transformer as the covers are not sufficiently heavy to support the tank and oil. Some of the

transformers in round tanks or in oval steel-plate tanks have rods which extend from the base or trucks up the side of the tank through the cover rim, and terminate in eyenuts. These eyenuts are for lifting the complete transformer (Fig. 208). Often on such transformers, rods terminating in eyenuts extend through the cover to the core clamps. These may be used for removing the cover, core, and coils but not the entire transformer. On other transformers small eyebolts are provided for lifting the covers alone (Fig. 208).

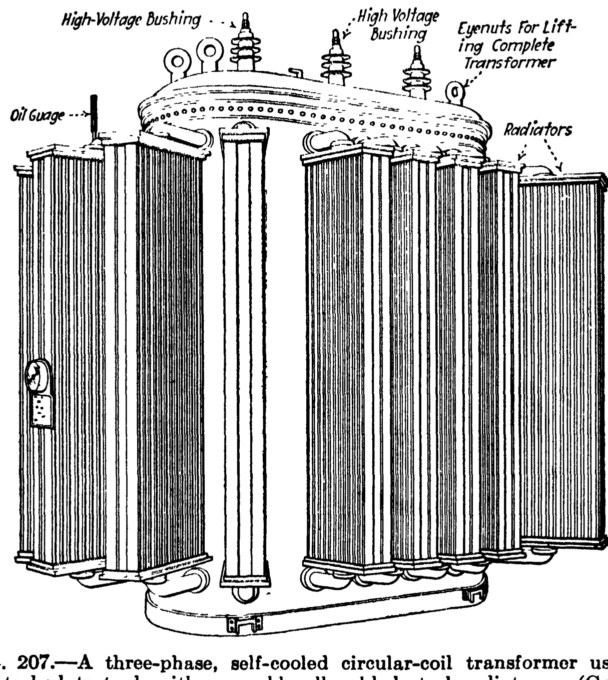


FIG. 207.—A three-phase, self-cooled circular-coil transformer using an oval steel plate tank with separable all-welded steel radiators. (GENERAL ELECTRIC CO., Schenectady, N. Y.)

291. NOTE.—CARE SHOULD BE TAKEN IN WORKING AROUND TRANSFORMERS that no tools, solder, or other foreign materials are dropped into the cases.

292. When No Crane Is Available, The Transformer may be skidded or moved on rollers into place. In doing so, care must be taken that it is not tipped over. A transformer with a round base is easily tipped and should therefore preferably be bolted to a temporary wooden frame or base before moving.

In fact all transformers without trucks (Fig. 208) should be provided with skids when they are being rolled to distribute the stress over the base.

293. NOTE.—THE TRANSFORMERS MAY BE LIFTED ONTO THE ROLLERS WITH JACKS.—Those equipped with trucks can be lifted by placing the jacks under the truck frame or transformer base. The transformers in round corrugated steel tanks which have overhanging cast-iron bases

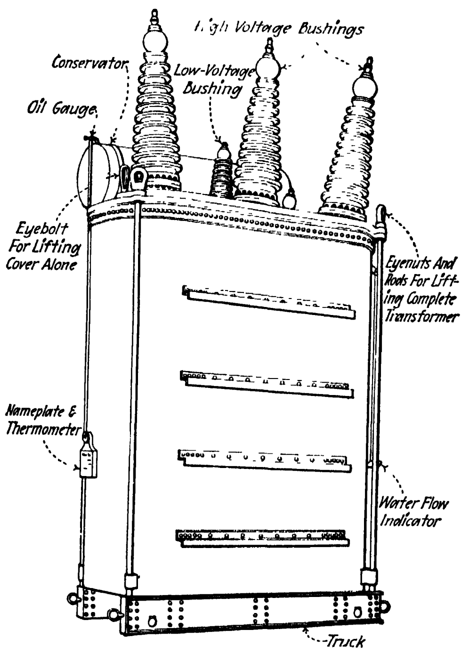


FIG. 208.—A three-phase, water-cooled, outdoor circular-coil transformer using an oval steel plate tank with conservator. (GENERAL ELECTRIC Co., Shenectady, N. Y.)

can be lifted by placing the jacks under the overhang of the base. Some transformers have jack bosses attached to the bases. The jacks should never be placed under the drain valve, cooling coil connections, radiator connections, or other attachments.

294. Before The Transformer Is Put In Service, It Should Be Thoroughly Inspected, because there is always a possibility of an accident, misplacement of parts, and condensation of

moisture during shipment and storage. Usually manholes are provided, through which the transformer can be inspected for the presence of moisture or mildew and for damage caused by mechanical shifting of parts due to splashing of oil. When there are no manholes in the cover, the covers must be removed. The valves at the base are usually sealed with ordinary lead seals. These seals should be intact upon delivery of the transformer. See that moisture does not enter after delivery, by keeping cover joints tight except during necessary installation operations.

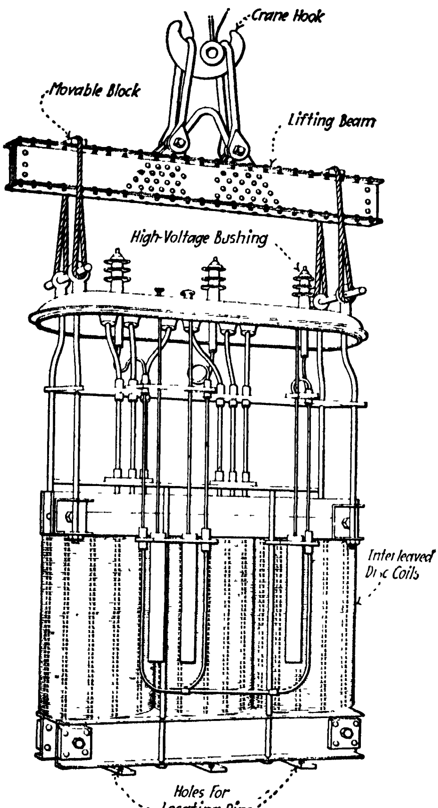


FIG. 209.—Showing the use of a lifting beam in raising a three-phase, inter-leaved-disc-coil transformer, "cover-lifter" type, from the tank. (GENERAL ELECTRIC CO., *Inst. Bk. No.* 85210-*A*.)

295. When The Transformer Is Received In Good Condition, no further inspection or draining will be necessary but test samples of oil should be taken from the bottom of the tank (Sec. 288). If the dielectric strength of the oil has reached the lower limit, the oil must be dried.

296. When The Transformer Is Received In Damaged Condition, in which case water or foreign materials may have entered the tank, the oil must be thoroughly dried. To exclude dirt and dust from the transformer, all gaskets should be carefully placed and all openings tightly closed as promptly as possible.

297. NOTE.—THE METHOD OF REMOVING THE COVER WILL DEPEND ON THE CONSTRUCTION OF THE TRANSFORMER.—On the "cover-lifter" type of transformer, (Fig. 209) the core and coils must be lifted with the cover, unless detachable conductor bushings (Sec. 306) or manholes in the cover are provided. When such are provided, the bushings may be removed, the eyenuts unloosened, and the cover lifted separately. When the cover and coils are raised for inspecting the transformer, they need only be lifted a short distance. The disadvantage of raising the cover and coils is that it is often difficult to locate them properly with the oil in the tank. However, the cover on a transformer of this type usually must be lifted. The reason is that the nuts on the extension bolts below the cover are tightened up before shipment to hold down the transformer and these nuts should be slackened ⅛ in. below the cover after installation and before the cover is finally tightened down. On a transformer of one of the other types, the cover is removed by taking off the bushings (Sec. 306), unscrewing the cover bolts, and lifting the cover with a crane hook which is attached with a sling to the eyebolts in the cover, or to the bushing holes.

298. NOTE.—NEARLY EVERY LARGE TRANSFORMER IS SUPPLIED WITH TWO OR MORE WEATHERPOOF VENTILATORS.—These are sometimes shipped detached from the transformer and must then be attached, in accordance with the outline drawing, after the transformer is installed.

299. NOTE.—THE COOLING COILS OF ASSEMBLED WATER-COOLED TRANSFORMERS SHOULD BE TESTED, if they look as though they have been damaged. The test is performed in the same manner as it is for coils shipped disassembled (Sec. 300).

300. Transformers Shipped Assembled Without Oil are set in place in the same manner as are those that are filled with oil. After the transformer is in position, the cover is removed (Sec. 301), and all dirt and dust is wiped from the castings and the porcelains. These are also examined for breakage or other injury. Any damage must be repaired and broken parts must be replaced. All leads are examined through out their length and all terminals are inspected as to condition and their position checked. The tank is thoroughly cleaned with cloths which do not lose lint readily. The lint will be held in suspension by the oil and decrease its dielectric strength. Any internal blocking, placed in the tank to keep the parts separated during transit, must be removed. Usually the parts to be taken out are marked, as for example with a red cross. All foreign materials should be removed. If the coils and insulation are very dirty, they should be washed with

clean, dry transit oil under pressure. When it is necessary, the *coil- and core-clamps are tightened. The transformer will* usually absorb moisture and thus it should be dried out before it is put in service. After it is dried out, it is closed tightly, and filled with oil.

301. NOTE.—TO CLEAN THE TRANSFORMER PROPERLY, THE CORE AND COILS USUALLY MUST BE LIFTED ABOVE THE TANKS.—The methods of removing the core and coils and of replacing them in position are described under setting coils in place in Sec. 305.

302. NOTE.—IN FILLING THE TRANSFORMER WITH OIL use metal hose if possible, see Sec. 287. It is desirable to fill the transformer through the bottom drain valve, because, with this method, aeration of the oil is prevented. This can be accomplished by employing a filter press or a small pump provided with a filter in the line. When such equipment is not available, the oil may be strained and poured in from the top in the same manner as it is for the small transformers, (Sec. 287). The tank should be filled to the level indicated by the marks on the oil gage, when the oil is at 25°C.

303. Transformers With Core And Coils Assembled But Shipped Separate From The Case are installed in a manner similar to those shipped assembled without oil (Sec. 300). The case must be thoroughly cleaned of all dirt and traces of moisture. Meanwhile the core and coils (transformer proper) if uncrated, should be covered with a cloth to exclude dust or dirt and should not be permitted to contact with water. Also, it must not be allowed to stand near open windows or doors. When the case is ready, it should be covered so that it will remain clean. The core and coils then should be cleaned and finally inspected as described in the preceding section. After being inspected they are placed in the case (Sec. 305). The case is closed tightly as soon as possible and then filled with oil.

304. In Setting A Transformer In Its Case, one must be careful that it is not injured and that it is properly located. A spreader (Fig. 209) should be used, in raising the transformer to prevent bending the lifting bolts or injuring the insulation with the hoisting ropes or chains. Any blow or scratch upon any of the windings may damage the insulation. Especial care must be taken in handling a transformer which is wound for high voltage because its coils must be extremely well

insulated. Each transformer is provided with some means of properly locating or centering it in its case. Various means of centering the transformer are employed. One method (used on most of the General Electric transformers) is to pro-

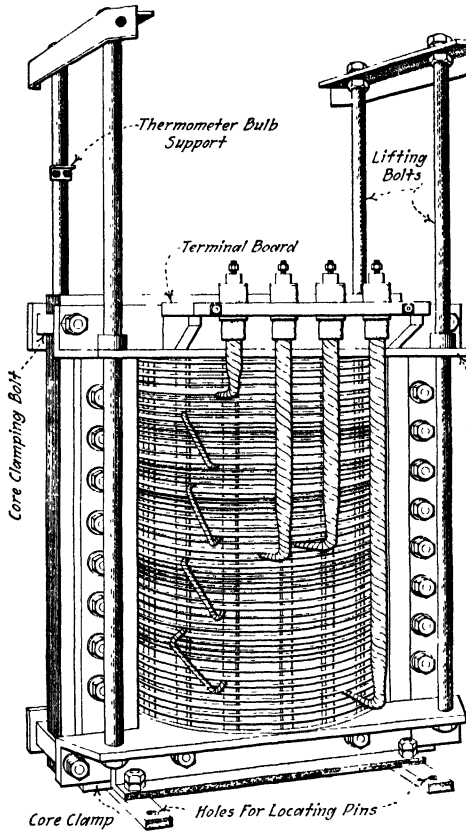


FIG. 210.—A single-phase, inter-leaved disc coil with two-part distributed core removed from the tank. (GENERAL ELECTRIC CO., *Inst. Bk. No.* 85210-*A*.)

vide holes in the iron straps at the bottom of the transformer (Figs. 209 and 210) which holes fit over pins fastened to the bottom of the case. Another method (used on some Westinghouse transformers) is to provide structural-iron legs on the

bottom of the transformer (Fig. 211) which set over lugs or other metal pieces attached to the bottom of the case. A light lowered into the case will enable one to see readily whether the transformer is in its proper position.

305. NOTE.—THE METHOD OF PLACING A TRANSFORMER (CORE-AND-COILS) INTO ITS CASE will vary somewhat with the type of transformer. On a transformer of one type, which is similar to those of the "cover-lifter" type (Fig. 209) except that it has separate rods and eye-nuts for lifting the complete transformer, the bushings are set in place and the leads connected, before the core and coils are put in place. The cover, core, and coils (Fig. 209) are then let down into the proper position in the case and the cover fastened tightly to the transformer case. On a transformer of any of the other types (Sec. 303) the core and coils (Figs. 210 and 211) are lifted into their proper place without the cover. The cover is bolted into place. The leads are then attached to the coils and the bushings set in place.

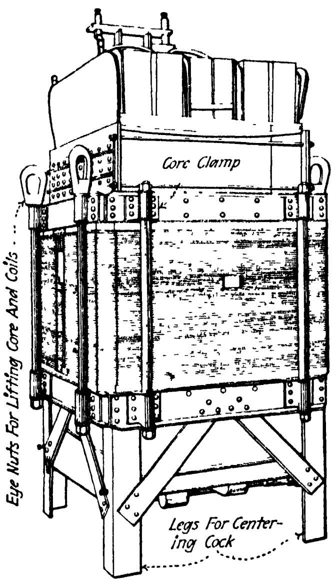


FIG. 211.—An oil-insulated, water-cooled transformer, of 14,000 kva., 150,000 volts, removed from its tank. (WESTINGHOUSE ELECTRIC & MANUFACTURING CO., *Inst. Bk. No.* 5094-*B*)

306. Bushings Of Various Types are employed, but for erection purposes they may be divided into two classes: (1) *Those with a detachable conductor.* (2) *Those with a conductor which is not detachable.* On the first class, consisting of what is called the tubular types, the cable conductor, which passes from the terminal board or winding through the metal tube to the terminal cap that connects with the external circuit, may be detached from the porcelain shell. Such a bushing may be disconnected from the terminal base or coils without entering the case. It is usually installed by connecting the detachable cable to the terminal board before the cover is in place. When the cover is properly placed, the shell of the bushing is mounted

on it. On the second class, consisting of the rigid and flexible conductor types, the conductor cannot be detached from the shell. A bushing of this class must be disconnected from the terminal board or winding before it can be removed from the cover. To install one of these bushings, it must first be mounted on the cover and then the lower end of the cable connected to the terminal board or winding through a manhole, after the rest of the transformer has been assembled. On transformers in which the cover is lifted with the coils, the cables may be connected to the terminal board before the coils and cover are let down into place.

307. NOTE.—A BUSHING BEFORE AND DURING INSTALLATION SHOULD BE KEPT CLEAN AND DRY, and should be carefully handled. In putting it in place, one must not strike it against the sides of the opening in the cover. The bushing outlets are usually provided with jackets. These must be placed in the proper position and the bushing bolted tightly in the case, particularly on outdoor transformers.

308. Disassembled Transformers may be considered as composed of two classes: (1) *Those with the core and coils disassembled.* (2) *Those with the case disassembled.* Only very large transformers are shipped with the core-and-coils disassembled. Special instructions are sent with each transformer and these should be carefully followed. No general method for assembling the coils will be given in this text. The methods and principles outlined in this division will apply to the assembly of this type of transformer as well as any other, but the details will vary. The assembling of transformers which have their cases or radiators shipped in parts will be generally treated. The transformer is erected as any assembled transformer except that the case and radiators or other parts must be assembled.

309. The Cooling Coil of a water-cooled transformer is sometimes shipped separate from the case. It should be set in place and the double-flanged connection, where it is brought through the tank, should be gasketed and drawn up tightly. Each flanged joint requires two cork gaskets which must be dipped in the bakelite varnish supplied before being used. On transformers of other types, stuffing boxes are employed around the cooling-coil entrance in the tank. These should

also be packed with a cork gasket dipped in bakelite varnish or with asbestos rope soaked in litharge and glycerine (three parts litharge and one part glycerine). When the cooling coil is attached to the cover, the ends of the outlets should be lagged above the oil surface to prevent condensation of moisture from the air in the tank. If the coil looks as though it were damaged, it should be tested. After the transformer is all assembled and filled with oil, the cooling coil is connected to the water system.

310. Note.—The Cooling Coil Should Be Tested At A Pressure Of 80 To 100 Lb. Per Square Inch.—If the coil is in the tank and the tank filled with oil, air should be employed as any leak will be located by observing the bubbles. One end of the coil is closed and air is pumped in at the other end. A pressure gage and a valve should also be connected in the line between the coil and compressor in the order named. When the pressure is obtained, the air supply should be disconnected and the fall in pressure in one hour observed. The cause of this fall, whether it is due to a leak in the coil or is in the joints between the fittings, must be determined. The water or oil method may also be employed. The water method, however, cannot be used when the transformer is filled with oil. The method is similar to the air method except that the coil must be pumped full of the liquid before it is closed. No air pocket should be allowed to form. If the connections are tight and there are no leaks in the coil, the pressure should hold practically constant for 5 minutes.

311. Radiators Are Sometimes Shipped Separately, as in instances where the transformers are large. The radiator must not be lifted by attaching hooks or slings to the sheet-metal parts of the headers or to the tubes. The radiators can be handled by temporarily bolting on the cast-iron connections and placing a sling under these attachments. The radiator can then be lifted vertically into place as shown in Fig. 212. The bottom connector, with its treated gasket (Sec. 314) is bolted to the tank. In a similar manner the upper connector is bolted to the radiator. Then the radiator is swung around into place with the sling, and the other two joints are made. After the transformer is warmed up in service, the joints should be examined for leaks and the bolts tightened if necessary.

312. Note.—The Radiators May Be Attached Without The Removal Of The Oil from the transformer case, when plugs are provided on the inside of the radiator openings. Such plugs are employed

whenever the clearances inside the case permit. They are held in place by the oil pressure and friction. After the radiator is installed, the plugs should be pulled out from the inside by means of ropes which are tied to a ring on the underside of the manhole cover. The radiators will then fill with oil. Additional oil must be added to replace that taken up by the radiators.

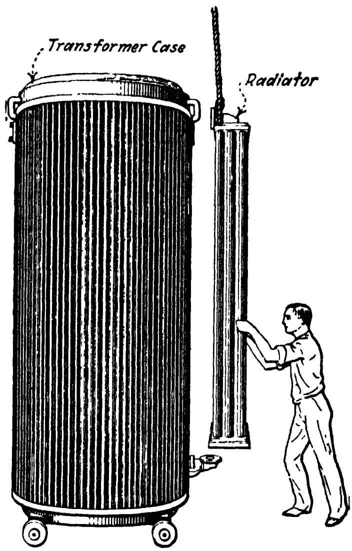


FIG. 212.—Showing a method of attaching a radiator to a transformer tank. (GENERAL ELECTRIC CO., *Inst. Bk. No.* 85210-*A*.)

313. NOTE.—WHEN THE RADIATOR OPENINGS ARE CLOSED WITH BLANK FLANGES, the oil must be removed from the transformer case, (if the case is filled) before the radiators are attached. The oil should, if possible, be replaced the same day that it is withdrawn as otherwise the transformer may have to be dried.

314. Gaskets Are Usually Of Composition Cork although in a few cases felt gaskets are employed. For joints below oil level, the small circular gaskets are dipped in bakelite varnish furnished with the transformer. The metal surfaces of the joint are cleaned and brushed with bakelite varnish just before the gasket is put in place. Large gaskets made in more than one piece are stuck to one metal surface with a thin coat of the varnish and held in place with weights until the varnish has set. The gasket and other metal surface are brushed with

varnish just before the joint is made. For joints above the oil level and for manhole-cover joints which must be frequently opened, the gasket is held to only one metal surface with a thin film of the varnish. The other surface is applied without treatment.

315. NOTE.—FELT GASKETS are immersed in linseed oil until the gasket is thoroughly saturated. The excess oil is squeezed out of the gasket and one side of it coated with a thin film of varnish furnished with the transformer. The gasket is stuck in place on one contact surface only.

316. The Oil Should Be Sampled And Tested Before Being Used.—In taking samples of oil from transformers, the oil should be taken from the bottom of the tank by means of a sampling valve. Enough oil should be drawn off, before the sample is taken, so that the sample will not be that which was stored in the sampling pipe. The sampling pipe and valve may be separate from the drainage pipe and valve or may be connected to the drainage valve by means of a suitable reducer. A glass receptacle is desirable for the sample since water, if present, can be readily observed. If no oil testing facilities are available, send the sample to the nearest office of the manufacturer of the transformer. The samples should be packed carefully and the corks sealed with paraffin or wax. Rubber corks should not be used (Sec. 287). One pint of oil is sufficient for a dielectric test, but for a complete test one quart is necessary. Drums of oil are sampled with sampling tubes, called *thiefs*, which will draw the oil from the bottom of the drum.

317. NOTE.—THE OIL SAMPLE SHOULD BE TESTED between polished brass or copper disc electrodes 1-in. in diameter which have a square edge. The axis of the discs should be horizontal and in the same line, and with a gap of 0.1 in. between their adjacent faces. The dielectric strength of the oil when shipped should be at least 22 kv. on such a test gap. Other test gaps are occasionally employed.

QUESTION ON DIVISION 3

1. Into what classes are electrical machines divided in this division?

2. How are electrical machines generally shipped?

3. In what different manners are rotational electrical machines usually supported?

4. Name the methods whereby a rotational electrical machine may be placed upon a foundation.

5. How should small machines (about 1 hp.) be lifted on a foundation?

6. Draw a sketch of, and describe, the method of sliding a machine onto a low foundation. How can the method be used when anchor bolts project above the foundation top?

7. When the foundation top is a considerable distance above the floor, what two methods may be employed for getting the machine on the same level with the foundation top?

8. Draw a sketch of, and describe, the method of lifting a machine with a block and tackle onto a foundation. Describe another method which may be employed when the foundation is high or wide.

9. Describe two methods of attaching a hoist to wooden members.

10. Describe a method of attaching a chain hoist to a ceiling.

11. Draw sketches of, and describe, two hooks for supporting hoists from structural steel members.

12. Explain two methods of supporting a hoist in a building which has concrete ceilings.

13. Illustrate how electrical machines which are to be mounted on wall or column supports are usually lifted into place. What other method may be employed?

14. Describe the method of preserving the relationship between the position of the brushes and the pole pieces when the end bracket is rotated.

15. Illustrate and describe a method of hoisting a motor to a ceiling, the hoists being in the story above the motor installation.

16. Draw a sketch of a method of hoisting a motor to a ceiling, the hoists being in the same story with the motor installation.

17. By what method can a motor be raised to a position close to the ceiling without cutting holes in the ceiling?

18. Sketch a method whereby a motor can be lifted against a concrete ceiling in which no holes can be drilled.

19. Show how a motor can be lifted to a position against a ceiling, which is provided with threaded sockets.

20. Illustrate a method of raising a motor into position on a wall.

21. By what means are motors and generators usually held to their supports?

22. What is the main difficulty in drilling holes in concrete with a chisel and a hammer? How may it be overcome?

23. Describe the principles of operation of the two types of hydraulic drills.

24. Explain the operating principle of the electric drill.

25. What is the important thing to observe in setting a large completely assembled machine on its foundation?

26. What are the parts in which disassembled machines are shipped?

27. Name and describe the three methods whereby disassembled machines are supported.

28. What is the first operation in the erection of a disassembled machine?

29. Describe the methods of lifting a bedplate onto its foundation.

30. Give the important points to be observed in the erection of bearing pedestals.

31. By what methods may the bearing pedestals be lifted into place?

32. How may the lower half of the frame be lifted into place?

33. Illustrate and describe a method of rolling the lower half of the frame into position.

34. What should be done to the rotating part of the machine before it is placed in the bearings?

35. Describe the usual method of placing the rotor in position.

36. Draw a sketch of, and describe, the method of rolling a rotor into position from the end.

37. Describe and illustrate a method of rolling a rotor into position from the side.

38. In what manner may an armature be pressed on a shaft while it is cold?

39. By what methods are large armatures which are not on their shafts supported?

40. What are the different manners in which a rotor or flywheel may be heated so that it need not be forced on the shaft? Which are recommended?

41. Describe a method of heating a flywheel with an electric heater.

42. What is important to remember when placing a rotor that is composed of sections on its shaft?

43. Describe one method of forcing a rotor on a shaft that was employed when the rotor stuck on the first attempt.

44. When and how may the upper half of an electrical-machine frame be lifted onto the lower half?

45. Illustrate a method of rolling the upper half of the frame into position.

46. On motor-generator sets which have a one-piece motor frame and a removable bridge, how is the motor frame brought into place?

47. How may the rotor be put in place on a synchronous motor?

48. Describe a method of properly spacing the brush arms and brush-holders on a direct-current machine.

49. Describe one method of checking the location of the neutral point on the commutator of a commutating-pole machine.

50. What inspection should be made when installing small transformers?

51. In filling small transformers with oil, what precautions should be taken?

52. Describe the method of erecting a large transformer shipped assembled and filled with oil.

53. Describe the different methods of removing the cover from a transformer.

54. In inspecting a transformer, what things should be observed?

55. What is the procedure in erecting an assembled transformer which was shipped without oil?

56. Give the preferred method of filling a transformer.

57. State the precautions to be taken in erecting a transformer which is shipped with the core-and-coils assembled but separate from the case.

58. Describe several methods of centering and lowering a transformer in its case.

59. In what two ways (depending on the type of bushing) may bushings be installed on the transformer cover?

60. How is the cooling coil fastened to the transformer tank? How can it be tested?

61. Describe a convenient method of attaching radiators to a transformer case.

62. How is the joint between a transformer tank and its cover usually made?

63. In what manner should the oil sample be taken from a transformer?

DIVISION 4

LOCATING AND FIXING ELECTRICAL MACHINERY

318. A Machine Must Be "Located" And "Fixed" After It Has Been "Erected" On Its Support.—"Erection," as the term is used in this book, means the placing of the machine on the support (see note below) which has been prepared for its reception. Erection is treated in Div. 3 It is the purpose of this division to explain how electrical machines may be located and fixed.

319. NOTE.—BY "A SUPPORT" FOR AN ELECTRICAL MACHINE IS MEANT the structure or member which is to retain the machine in its operating position. Thus, a support may be a specially constructed foundation, a motor shelf, platform, bracket, or sustaining frame or—for small or relatively small machines merely a part of a floor or ceiling on which the machine is to be installed.

320. "Locating" A Machine, as the term is used in this book, means the *accurate* placing of the machine in the *exact* operating position which it should occupy.

321. "Fixing" means the securing of the machine in the exact operating position which it should occupy—after it has been aligned therein.

322. NOTE.—BEFORE PRESENTING SPECIFIC PROCESSES WHICH ILLUSTRATE THE COMPLETE PROCESSES OF LOCATING AND FIXING ELECTRICAL MACHINES of different types, certain appliances and detail methods, which are employed, will be discussed.

323. Levels For Locating Machinery are of the general types: (1) *Vial or bulb levels,* sometimes called *spirit levels,* Fig. 213. (2) *Surveyor's levels,* which are provided with a telescope, Fig. 214. In the past, the bulb levels were used almost exclusively. But as the sizes of machines increased and the importance of accurate locating became of greater consequence, surveyor's levels automatically came into use. The

surveyor's levels have been used particularly in the erection of large, sensitive machines such as turbo-generators. Spirit levels remain the most satisfactory for medium- and small-

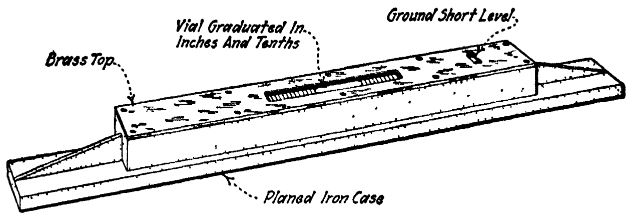


Fig. 213.—"Queen" machinists' level. They are manufactured in 12, 18 and 24 in. lengths and have an accuracy of 1 min. angular measurement for a 0.1 in. vial graduation. (Queen-Gray Co., Philadelphia Pa.)

sized machines. The characteristics and use of levels of each of these two types will be discussed.

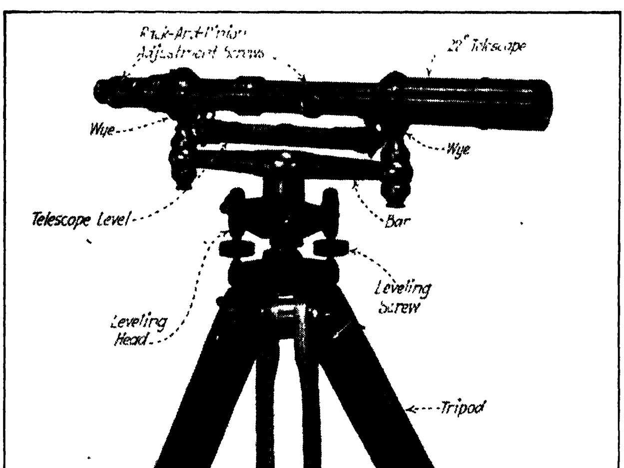


Fig. 214.—Surveyor's level, engineer's wye-level type, especially designed for machinery erection. It has a 22-in. telescope and an especially accurate and sensitive level bulb or vial. It is sufficiently sensitive that the warmth of one's hand on either end of the wye will change the position of the bubble very quickly. (W. & L. E. Gurley, Troy, New York.)

324. Note.—Economy Forced The Use Of Surveyor's Type Levels.—Where spirit levels were applied for aligning medium- and large-sized machines, it was necessary also to employ straight edges. For

large machines, the straight edges had to be so long and were so expensive that their first and transportation costs became almost prohibitive. Furthermore, accurate leveling may, for large machines, be done more rapidly with proper surveyor's-type levels and targets than with spirit levels.

325. Spirit Levels (Figs. 213, 215, 216, and 217) are manufactured in many designs and degrees of accuracy. In

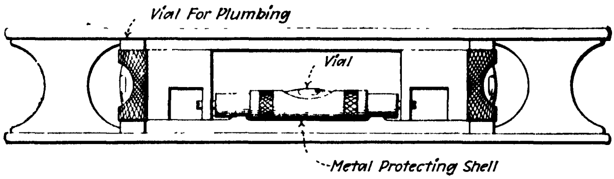


FIG. 215.—Metallic plumb and level. This instrument is nickel plated, is fitted with ground vials and both the plumb and level vials are protected by a metal shell or cover. These covers can be turned so as to entirely cover the vials when the level is not being used. (STANLEY RULE & LEVEL COMPANY New Britain, Conn., level No. 37, 12 in.)

general, the more expensive the level the greater its accuracy. A level (12-in. size) like that of Fig. 215, lists at about $3, that of Fig. 216 at $4.50, that of Fig. 213 at $18, and that of Fig. 217 at $45. The accuracies of these levels are, approxi-

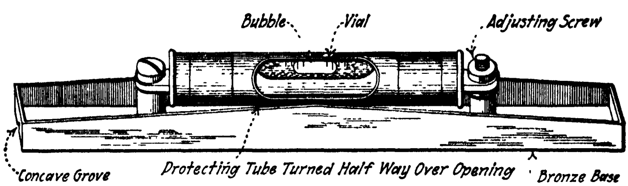


FIG. 216.—Electrician's level. The base is made of bronze, hence is not affected magnetically. The level has a concave groove in its base, running through its center full length, this adapts it for resting on a shaft or pipe as well as on a flat surface. The glass tube or "vial" is graduated and may be obtained either plain or ground. Each vial is set in an adjustable brass tube. This adjustable tube has around it an outer tube which may be turned to cover and protect the glass vial when not in use. The level can be furnished in 8 in., 12 in., and 16 in. lengths. (L. S. STARRETT COMPANY, Athol, Mass.)

mately, about in proportion to their prices. The levels of Figs. 215 and 216 will be satisfactory for aligning small, comparatively-rugged machines. But, for satisfactory operation, the larger and more sensitive machines must be aligned with

the expensive and accurate levels. Often a *V* groove, (Fig. 218) is planed in one face of a spirit level to facilitate its use on shafts and similar small-diameter, circular-section members. The methods of using spirit levels for erecting machinery are described in Sec. 337.

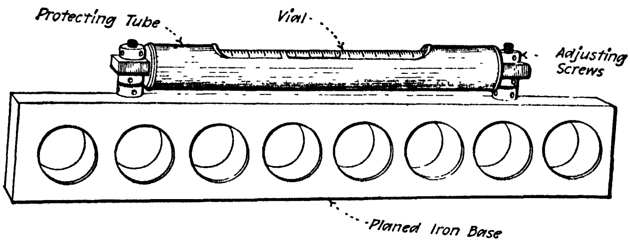


FIG. 217.—"Queen" precision machinist's level. This also is manufactured in 12, 18 and 24 in. lengths. It is equipped with a vial of extra sensitiveness and has an accuracy of from 5 to 8 sec. angular measurement for a 0.1 in. vial graduation. (QUEEN-GRAY Co., Philadelphia, Pa.)

326. NOTE.—WHY SPIRIT LEVELS ARE SO CALLED is because the liquid in the vial is a "spirit"—a mixture of alcohol and ether.

327. The Accuracy And Sensitiveness Of Any Spirit Level Are Determined By The Radius Of Curvature And The Accuracy Of Grinding Of Its Glass Vial.—The meaning of "radius of curvature" is illustrated in Fig. 219. The greater the radius of curvature, the greater the sensitiveness of the level. A level vial must have curvature, otherwise the bubble would, when the vial was inclined, always tend to shift to the extreme higher end of the vial.

328. NOTE.—THE ORDINARY LEVEL OF THE HARDWARE OR MACHINIST'S SUPPLY STORE IS NOT, USUALLY, VERY ACCURATE.—The glass vials in them are not, ordinarily, ground accurately, but are often merely bent to an approximate curve. Levels of the types shown in Figs. 216 and 215 may be obtained with ground vials.

329. NOTE.—IN CONSTRUCTING AN ACCURATE SPIRIT LEVEL, (Figs. 213 and 217) a piece of glass tubing of suitable structure is selected. This tube is ground on the inside to a barrel shape. The regularity of form and accuracy of grinding determine the sensitiveness and accuracy of the resulting spirit level. The tube is filled with a proper mixture of alcohol and ether and carefully sealed. A spirit level of maximum accuracy is the result of a combination of skill, experience, and good fortune. Out of many precise levels there may perhaps be found occasionally one of

superlative excellence, due to the happy combination of all of the factors necessary to the production of a level of the highest possible accuracy and sensitiveness. (QUEEN-GRAY Co.)

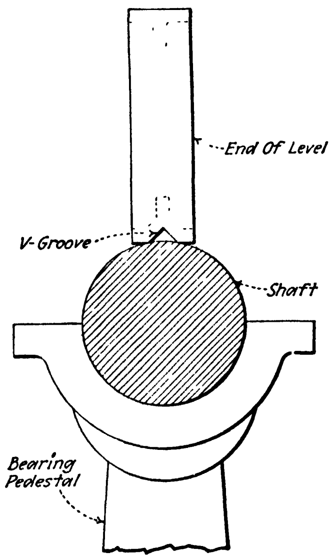


FIG. 218.—V-groove of level resting on shaft.

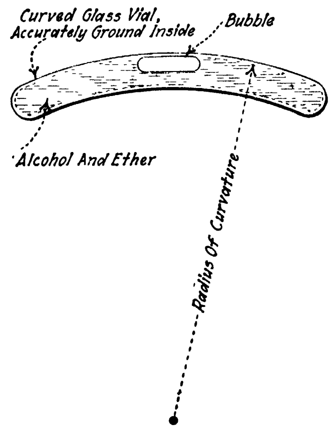


FIG. 219.—Illustrating "radius of curvature." The vial which is shown is of exaggerated curvature to better illustrate the idea.

330. The Sensitiveness Of A Spirit Level Is Expressed By The Number Of Angular Degrees (Or Angular Units) Inclination Which Is Necessary To Cause The Bubble To Shift A Given Distance In Its Vial.—Thus, if when the spirit level of

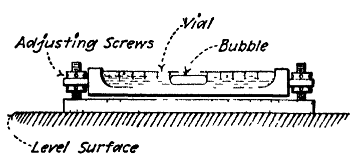


FIG. 220.—Bulb in horizontal (level) position, bubble in center.

Fig. 220 is inclined 1 deg. (Fig. 221) from its original position and the bubble, due to this inclination, is shifted in the vial 0.1 in., then the level has a sensitiveness of 1 deg. *angular measurement to a* 0.1-*in. scale division* (the picture is not to scale;

it is used merely for illustration). Spirit level scales are, usually, graduated with 0.1-in. scale divisions. Hence, if it is specified that "*the sensitiveness of a level is* 8 *sec.*," this means, ordinarily, that a change of inclination of 8 sec., angular measure, of that level will cause its bubble to shift 0.1-in. in its vial. The length of the base on which the vial is carried is not, and need not be, considered as a factor in this matter of sensitiveness. It is curvature (Fig. 219) of the vial which determines the sensitiveness.

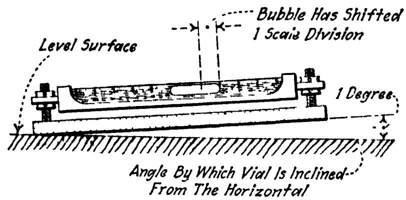


FIG. 221.—Vial inclined 1 deg. from the horizontal or "level" position.

331. NOTE.—THE CURVATURE OF LEVELS OF VARYING DEGREES OF SENSITIVENESS is shown in the following table (QUEEN-GRAY CO.)

Sensitiveness of level, in angular measure (Value of the angle of inclination which is required to produce a shift of 0.1 in. of the bubble in the vial)	Corresponding radius of curvature of vial, in inches
2 seconds	1,718
5 seconds	687
10 seconds	543
20 seconds	171
30 seconds	114
1 minute	57
1 degree	0.95

332. To Determine The Sensitiveness Of A Spirit Level, that is, the angular value of one of its scale divisions, proceed as in the following explanation. For accurate alignment or for comparing different spirit levels for accuracy, it is often desirable to make such determinations.

333. Explanation.—Support the level (Fig. 222) on a block (preferably metal although wood may do) in such a way that the block bears

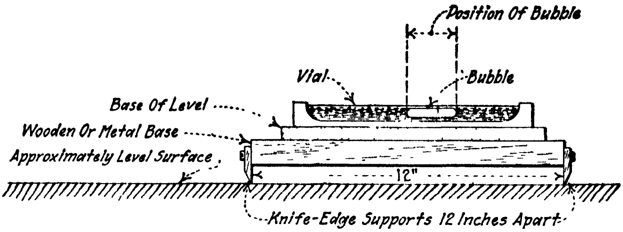


Fig. 222.—Determining the sensitiveness of a level and the angular value of one of the scale divisions; first step.

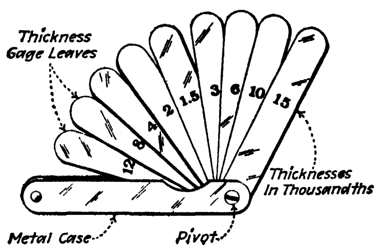


Fig. 223.—Folding-type thickness gage. This type is popular with erection men for determining air-gap values and for finding the thickness necessary for liners The leaves are tempered. Each has its thickness, in thousandths, etched on it.

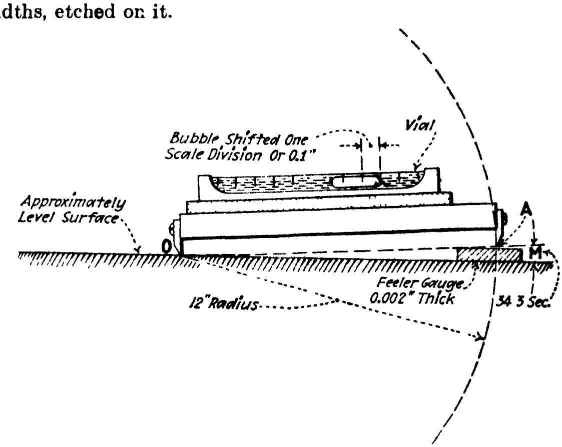


Fig. 224.—Determining the sensitiveness of a level and the angular value of one of its scale divisions; second step.

only on two knife-edges, which are located exactly 12 in. apart. Insert shims under one of the knife-edges so that the bubble will be shifted to a

position near the center of the vial. Note carefully the position of the bubble in relation to the scale-division line nearest one of its ends. Now insert a leaf of a thickness gage (Fig. 223), say 0.002 in. thick, under one of the knife-edges (Fig. 224). Assume that thereby the bubble is shifted by 0.1 in., or 1 scale division. Then, the angular measurement value for 1 scale division of the level would be found as follows:

The distance from O to A (Fig. 224) is 12 in., which is the radius of a circle. This circle has a circumference of: $2 \times \pi \times r = 2 \times 3.1416 \times 12$ in. $= 75.398$ *in.* This 75.398 in. is equivalent to 1,296,000-sec., angular measurement, since there are 1,296,000 sec. in a circle. Hence, 75,398 in. circumferencial distance is equivalent to 1,296,000 sec. angular measurement. Now: Determine (by applying the rule of proportion) the angle M through which knife-edge A has been raised by the insertion of the 0.002-in.-thick liner.

Thus: $$\frac{\text{Sec in angle } M}{\text{Sec. in entire circle}} = \frac{\text{In. in angle } M}{\text{In. in entire circle}}$$

hence: $$\text{Sec. in angle } M = \frac{(\text{In. in angle } M) \times (\text{Sec. in entire circle})}{\text{In. in entire circle}}$$

substituting: $$\text{Sec. in angle } M = \frac{0.002 \times 1{,}296{,}000}{75{,}298}$$

solving: $$\text{Sec. in angle } M = 34.3 \text{ sec.}$$

Therefore, the 0.002 in. at A is equivalent to 34.3 *sec.* Hence, the bubble was shifted (as explained above) 0.1 in., along its scale on the vial, by raising A through an angle of 34.3 sec. Therefore, the level shown in Fig. 224 has a sensitiveness of 34.3-*sec. angular measurement to a* 0.1-*in. scale division.*

334. The Sensitiveness Most Desirable For Average Use, under ordinary conditions, in the erection of machinery is 1-*min. angular measurement to a* 0.1-*in. vial scale graduation.* However, in erecting machines of certain types, where the bed is solid and vibration is absent, a level of greater sensitiveness and of greater precision may often be employed to advantage. Special levels of this character, of any degree of precision can be supplied. (QUEEN-GRAY CO.)

335. NOTE.—AN INSTRUCTION FOR LEVELING MACHINE TOOLS, from the *Instruction Book Of the American Tool Works Company*, Cincinnati, Ohio, follows in substance. While this relates specifically to machine tools, the statement which it makes is equally applicable to the leveling of electrical machinery. "Never try to level a machine with a short machinist's or carpenter's level. They are not sufficiently sensitive and positively will not produce results. A first-class metal level, about 18 in. long, with a graduated vial (as made by a high-class manufacturer) must be used."

336. Precision Vertical Levels (Fig. 225) are sometimes employed in machinery erection for the accurate plumbing of vertical members. The arrangement of this instrument is obvious from the illustration. Its general construction is substantially the same as that of the precision levels of other types which have been hereinbefore described. A precision level of a new design (Fig. 226) which has recently been developed by the Queen-Gray Co., may be used as either a horizontal or a vertical level.

337. The Process Of Leveling Machinery With A Spirit Level (Fig. 227) will vary somewhat for machines of different types. To level a machine longitudinally, it is usually best to place the level on the shaft (Fig. 228). A *V* groove (Fig. 218) planed in the bottom face of the level renders it more convenient for this service. In cross leveling, some plane surface of the machine (Fig. 229), upon which the level may be placed at right angles to the

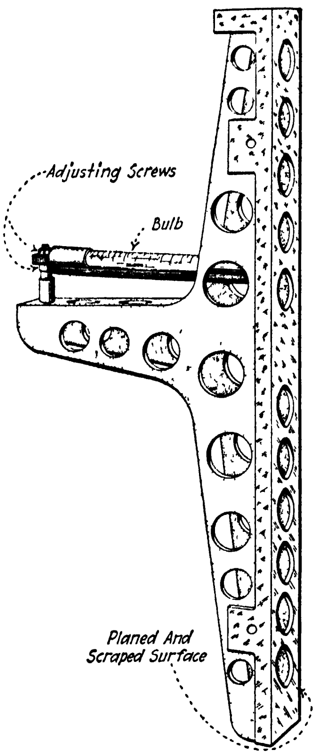


Fig. 225.—"Queen" precision vertical level which is made in 18 and 24 in. lengths. It has an accuracy of from to 5 to 8 sec. angular measurement for a 0.1 in. vial graduation. (Queen-Gray Co., Philadelphia, Pa.)

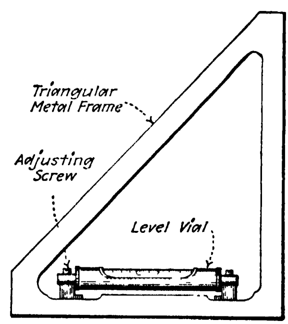


Fig. 226.—Precision level which may be used for either horizontal or vertical leveling. (Gray Co., Philadelphia.)

shaft, is often available. If such a surface of sufficient length is not available, then it may be desirable to construct an adjust-

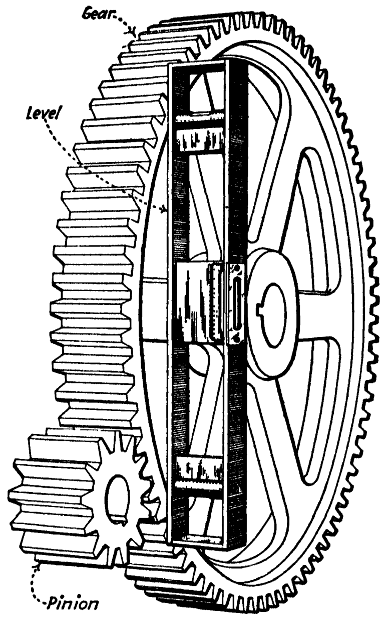


FIG. 227.—Leveling a gear and pinion.

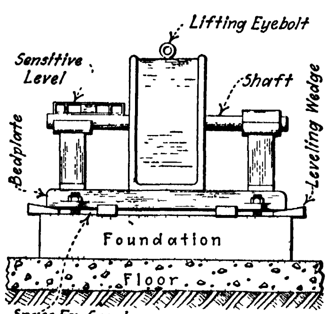


FIG. 228.—Leveling a machine lengthwise with level on shaft.

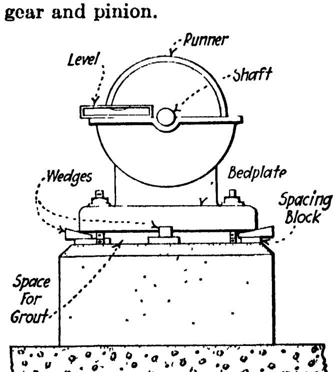


FIG. 229.—Leveling a rotary pump "cross-wise" with the level on the flange of the runner casing.

able level support (Fig. 230) the legs of which may straddle the shaft and rest on the planed surface of the bearing housing.

338. NOTE.—IN LEVELING A BEDPLATE WITH A SPIRIT LEVEL (Fig. 231) the level is placed across the finished pads on the surface of the

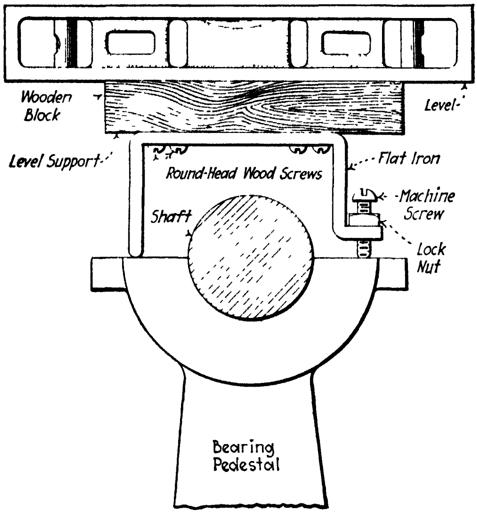


FIG. 230.—A level support used for leveling "cross-wise" on planed surfaces on a bearing pedestal.

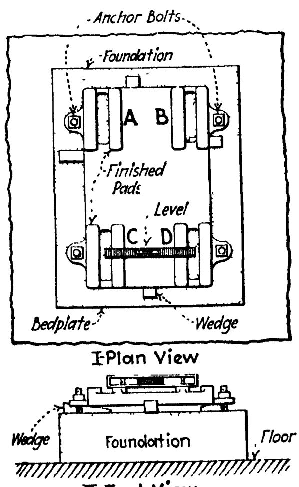


FIG. 231.—Leveling a bedplate with the level across pads.

bedplate. It is first placed across *AB* and the bedplate is leveled in this direction. Then successively it is placed across *BD*, *DC*, and *CA*, the

bedplate being leveled for each of these leveling locations. Finally, after the nuts on the anchor bolts have been set up tightly, the level is again tried in each of the four positions as a check. If the level is of insufficient length to bridge between the pads, then a leveling bar, which may be of either planed wood or metal, of sufficient length to span the pads, is placed across them and the level itself is carried on top of the bar.

339. A Hydrostatic Level (Fig. 232) may often be employed for leveling. Figure 233 illustrates the process of leveling a

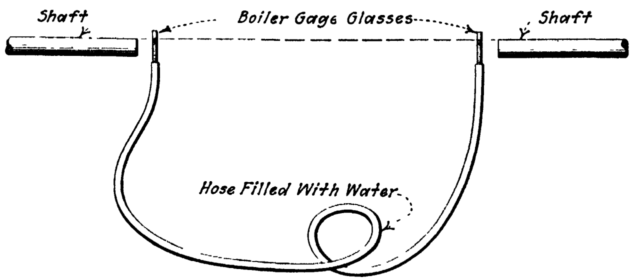


FIG. 232.—Illustrating the principle of the hydrostatic level.

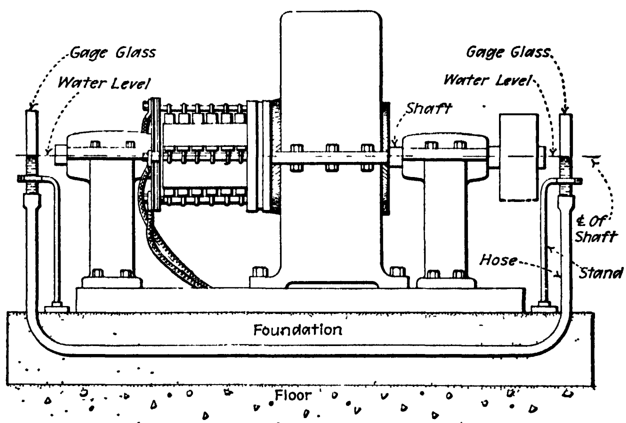


FIG. 233.—Leveling a machine longitudinally with the hydrostatic level.

machine longitudinally. Levels of this type which have metal-enclosed, graduated glasses are regularly manufactured, but one can be improvised as indicated in the illustrations. It comprises a rubber hose—garden hose is quite satisfactory—in each end of which an ordinary boiler-gage glass has been

inserted. Such a level can be used also for aligning shafting and for transfering a given horizontal level in construction work. Where the device is to be used by one man unaided, it may be desirable to attach each of the ends which contain the gage glasses to a block of 6 by 6-in. timber which will constitute stands.

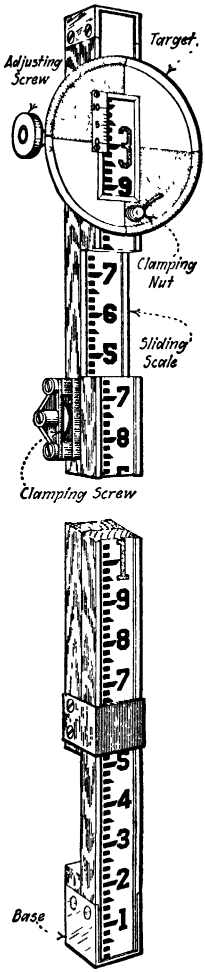
340. NOTE.—TO USE THE HYDROSTATIC LEVEL, fill the hose and glasses full of water. This is best done by submerging the whole in a tub of water—to insure that all air will be expelled. Sufficient water is now poured out that, when the upper ends of the two gage glasses are held side by side, the water level in each glass will be about half-way between the top and the bottom of the glass. Then the level may be used as suggested in Figs. 232 and 233. The water levels in the two glasses will always be the same elevation.

341. Engineer's Or Wye Levels Are Used In The Erection Of Large Machines, such as turbo-generator sets.[1] Ordinary surveyor's levels were first used by the General Electric Co. but they were not sufficiently accurate. The level illustrated in Fig. 214 was first manufactured especially to satisfy the General Electric Company's requirements. It has been found quite accurate and satisfactory. The method of using the engineer's level in leveling machinery is described in the following Sec.

342. A "Target" Must Be Used In Conjunction With An Engineer's Level.—In leveling machinery, the engineer's level and a target are employed in about the same manner as when they are applied for leveling different parts of a building structure, as is explained under following Sec. 343. No target suitable for machinery erection purposes was commercially available when the engineer's level was first utilized in this service. Therefore, it was necessary for the erectors who used this method to develop satisfactory targets. Such targets are described below.

343. NOTE.—THE STANDARD SURVEYOR'S TARGET IS NOT SUITABLE FOR LEVELING MACHINERY.—Such a target is shown in Fig. 234. With a target of this general construction, it is difficult to read elevations to even the nearest 1/16 in., which is 0.015,625 in. In leveling certain machinery it is necessary to be able to read to 0.001 in. The *blind spot,*

[1] See article, "Devices For Leveling Large Machines," by N. L. REA in *General Electric Review* for June 1924.



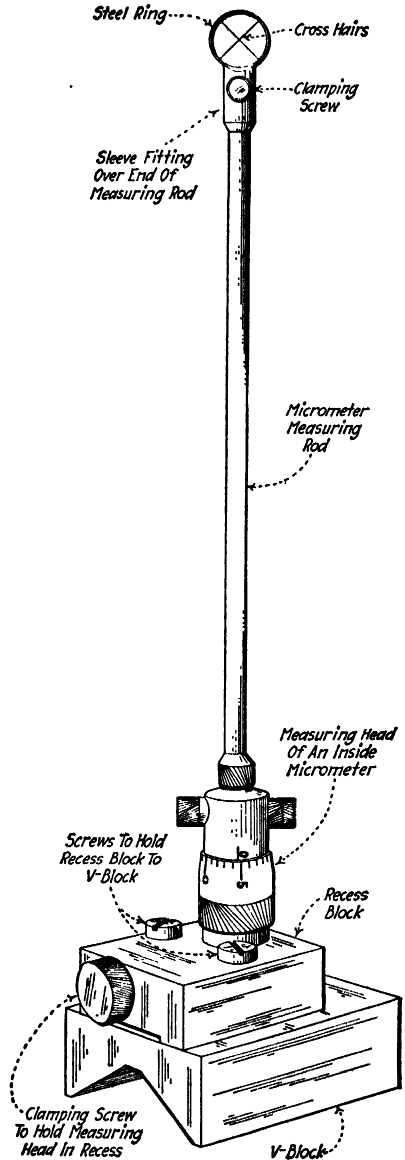


FIG. 234.—Typical surveyor's leveling rod and target.

FIG. 235.—Satisfactory type of leveling target for use with engineer's level. This target was assembled from a standard Starrett inside micrometer and a Starrett height gage attachment, Cat. No. 447, which was attached to a V block, by a tool maker, so that it could be used on a shaft. The stem of the top piece or of the target proper has a hole in it into which fits nicely the top end of the inside micrometer measuring rod; the target stem may be clamped on the rod with the set screw.

which always occurs, back of the cross hairs (at the sighting end) in the surveyor's or an engineer's level, is quite appreciable when the target is at a considerable distance from the instrument and may be several times wider than the finest hair-line mark on the target. An endeavor was made by the General Electric Co. erectors to overcome this defect. They drew two parallel lines (on a plate which was attached to a surveyor's-type target) with sufficient space between them, that the cross hair would not completely cover this space. In use, an effort was made so to elevate the target that the instrument cross hair would lie exactly midway between the two lines. But the arrangement was not successful. The lines were difficult to see and light reflection from the target and from the lines themselves confused the instrument man.

344. The Type Of Target Which Is Found Most Satisfactory For Machinery Leveling (Fig. 235), by the erecting men of the General Electric Co. who developed it, comprises two cross hairs supported in a ring. The target is supported on a *V* block. This block is arranged to clamp the measuring head of an inside micrometer. The target itself is a steel ring which is designed for mounting on the end of the micrometer measuring rod. A measuring rod of any length, which will satisfy local conditions, may be used. The erector is ordinarily interested only in variation of height of different locations. This height variation is read from the micrometer.

345. Note.—The Construction Of The General Electric Co. Micrometer Target (Fig. 235) is this: The steel ring has mounted across it, at right angles to one another and an angle of 45 deg. to the axis of the measuring rod, two 0.003-in. diameter steel wires. The base which is shown and the V-block are standard equipment. Their design may be altered to satisfy local requirements. A somewhat larger base having attached to it a small round-type level (to insure that the staff will always be plumb when the instrument is in use) might be a valuable addition. The steel ring and cross wires constitute the important feature of the instrument.

346. Explanation.—In Using The General Electric Co. Micrometer Target, a sheet of white paper is held back of the target, at the proper angle to "catch" the best light. This white background throws the cross hairs of the target and the cross hair of the Wye level in pronounced silhouette. The result is accurate readings—and no eye strain due to reflected light. The eye of the instrument man automatically tends to bisect the angles of the target cross hairs with the cross hair of the instrument. A $\frac{1}{1,000}$-in. variation from the true bisecting position of the hairs is quite apparent.

347. Plumb Bobs (Fig. 236) for machinery location should be rather heavy. If a plumb bob is not sufficiently heavy, it is too readily shifted. A bob of the type of Fig. 236, which is 3¾ in. long, weighs 12 oz., and costs about $1, is very convenient. A smaller bob of the same type, 3½ in. long weighing 8 oz., can be purchased for about 75 cents; it is quite satisfactory for the lighter work.

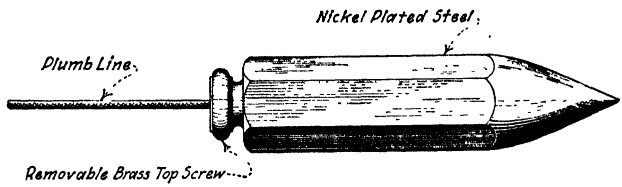


FIG. 236.—Plumb bob suitable for machinery locating.

348. In Describing The Processes Of Locating And Fixing Electrical Machines They Will Be Divided Into Four Different Classes: (1) *Rotational electrical machines which are shipped assembled.* (2) *Rotational electrical machines which are shipped disassembled.* (3) *Non-rotational electrical machines which are shipped assembled.* (4) *Non-rotational electrical machines which are shipped disassembled.* These are the same classes into which the machines were divided, in Div. 3, for the purpose of discussing "Erection." Methods of locating and fixing machines of each of these four classes will now be discussed in the order given.

349. The Support Itself And The Anchor Bolts Therein, If Any, Provide Approximate Location.—Assuming that the support has been properly erected or provided at the desired place, then, the machine, when set on it, should be in approximately the operating position which the machine should ultimately occupy. If correctly located anchor bolts are in the support, these will, when the machine is set over them, further insure the proper approximate location of the machine. But an approximate location is not, ordinarily, sufficient for satisfactory operation. In an approximate location, the machine will not be exactly level nor at proper elevation, nor in exact final alignment in the horizontal plane. Thus after it has

been erected (Div. 3) on its support, the machine must be accurately located and fixed before it can be operated.

350. The Locating And Fixing Of Rotational Electrical Machines Which Are Shipped Assembled will now be discussed, see Sec. 348 for classification. Such machines do not, ordinarily, require the alignment of the component parts within the machine itself—such alignment is made by the machine's manufacturer at his factory. Usually, the machine as shipped by him is ready for operation; sometimes a few minor internal adjustments may first be necessary. Small- and medium-sized motors and generators and similar rotational machines are, in most cases, thus shipped assembled.

351. In Selecting The Location For A Motor, Accessibility And Clearances Must Be Considered.—The machine should be accessible so that it may be cleaned readily and its oil wells may be reached without difficulty. Also, the relation of the motor location to that of its starter should receive attention. There should always be sufficient clearance that the motor may be shifted, on its slide rails or bedplate, to provide for belt tightening; the machine should not be mounted so close to a column or beam that this may be prevented.

352. What The "Locating" Of A Rotational Electrical Machine, Which Is Shipped Completely Assembled, Comprises, may be listed thus: (1) *Placing the machine at proper elevation, that is, raising or lowering it to its correct operating elevation.* (2) *Aligning the machine—in the horizontal plane—with some other machine, which it is to drive or which is to be driven by it, or with the building in which it is installed.* (3) *Leveling the machine so that it sets plumb.* Usually these three operations must be performed simultaneously; the correctness of each must be checked continually as the locating proceeds. But in certain cases the operations may be performed consecutively, in which case the order will, ordinarily, be that given.

353. Note.—The Locating Of Self-Contained Rotational Machines, which are shipped assembled, such as small- and medium-capacity motor-generators and frequency changers, does not, ordinarily, involve accurate ranging. That is, since these do not have to "line up" with other driven or driving machines, it is usually satisfactory if they are so located that their center lines lie approximately parallel with the walls

of the building. They should be so located that they look "square with the world." Usually, they can be so located, with sufficient accuracy, by using a measuring tape, or a measuring stick. Nor do they ordinarily have to be established accurately at a given elevation. These machines must, however, be leveled accurately. Except as just noted, the process of locating a self-contained rotational machine is the same as that for a machine which drives or which is driven, the steps in which process are specified in preceding Sec. 352.

354. There Are Two General Methods Of Locating Rotational Electrical Machines Which Are Shipped Assembled: (1) *The Cut-And-Try Method* (Fig. 240), in which the machine itself is immediately placed in approximately the position it will ultimately occupy, is adjusted and leveled into final accurate alignment, and is then bolted in this position. (2) *The Measurement Method* (Fig. 250), wherein the holding-bolt locations for the machine are first determined, by measurement (so that the machine will be accurately lined up when it is held by bolts in these locations), then the machine is set over bolts in these locations, leveled into final alignment, and bolted.

355. The Application Of The Cut-And-Try Method Of Machine Locating is, obviously, feasible only when the machine which is to be aligned is available. Also it is, ordinarily, feasible only for a machine which is to be supported on the floor or on a platform; it is not feasible for machines which are to be mounted inverted on ceilings or vertically on side walls. Holding the inverted or vertical machine, while aligning it, is difficult. It is desirable only for small- and medium-sized machines. The measurement method is always the more economical for large machines, because of the effort (and men) and time required to shift a large machine into alignment. Furthermore, it is not, usually, feasible if the machine requires a foundation; in such cases the anchor bolts must be accurately located in the foundation when it is being built. The cut-and-try method may occasionally be used effectively for aligning small machines, on foundations, masonry floors, or similar supports: The machine may be properly aligned on the support and the anchor-bolt locations marked on the support, using the machine bedplate as a templet. Then, the machine is removed and holes are drilled,

for the anchor bolts, at the marked locations. Expansion bolts or machine bolts may be used for anchor bolts. The machine bolts are cemented in, see Fig. 35 and the author's "Machinery Foundations And Erection."

356. The Application Of The Measurement Method Of Machine Locating becomes necessary when the machine is not available. Thus, it must always be used when the support is prepared prior to the receipt of the machine. It becomes necessary when a foundation support is to be built and the anchor bolts—or casings and pockets for them—are to be built into the foundation. For these foundations, an anchor-bolt templet must be used; see the authors "Machinery Foundations And Erection." It is, usually, necessary for all ceiling and vertically wall-mounted machines. It is ordinarily desirable and most economical for all but relatively small machines.

357. In Locating A Motor Which Is To Be Belted To A Shaft, There Should Be The Proper Distance Between The Motor And The Shaft.—This distance should neither be too small nor too great. A rule for determining the distance which

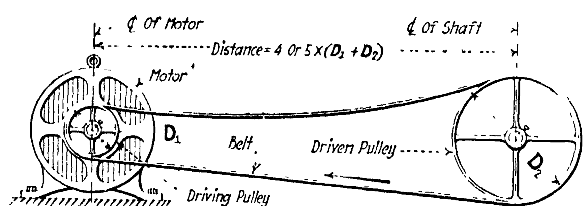


FIG. 237.—Determining the distance which a motor should be set from the shaft which it drives.

will give best results is: *Make the distance between the pulley centers* 4 *or* 5 *times the sum of the diameters of the two pulleys* (Fig. 237). This distance should not be less than 3 times the sum of the diameters, see the following example. If the distance is too great, the belt will flap; if too small, the belt will have to run too tightly for best operation.

358. EXAMPLE.—A motor pulley is 12 in. in diameter, and the line-shaft pulley, which it is to drive, is 24 in. in diameter. How far from the line shaft should the motor be located? SOLUTION.—*The sum of the diameters of the two pulleys* = 12 + 24 = 36 *in.*, or 3 *ft.* Then by the

above *rule, the distance between the motor pulley and shaft pulley* = 4 or 5 × 3 = 12 or 15 *ft.*

359. The First Step In Locating, By The Cut-And-Try Method, A Rotational Electrical Machine Which Is Shipped Completely Assembled Is To Place It At Its Proper Elevation. As explained in Sec. 354, the cut-and-try method is effectively applicable only to relatively small machines which are mounted on some floor, platform, or other surface which is not provided with anchor-bolt holes. It is assumed that this surface has been provided. The machine is placed on the surface, which will usually be at the elevation which the base of the machine should ultimately have. If it is not at the proper elevation, then a raiser should be inserted to raise it to the proper elevation. However, this raiser should not be installed permanently until after the machine has finally been aligned and leveled as outlined in following sections.

360. Raisers may be of timber (Fig. 238) where the supporting surface is of wood; or of concrete where the

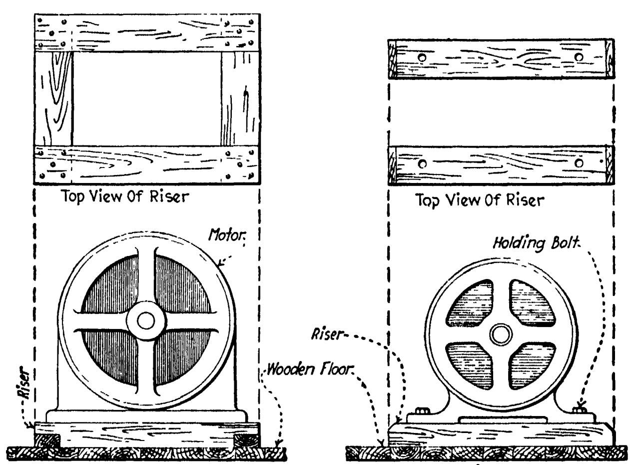


FIG. 238.—Timber raisers for raising machines to correct elevation.

supporting surface is of concrete. A wooden raiser may comprise two parallel timbers or planks (Fig. 238-*II*) or it may be of a rectangular timber frame (Fig. 238-*I*). A concrete raiser, where required (Fig. 239) may be poured, in a wooden form, or,

if it is not too high, the layer of grout under the machine (provided as described in following Sec. 433) may constitute the riser. Wherever a machine—unless it is very small—is to rest on a concrete surface, provision should always be made for a layer of grout under it. Where only the grout layer is necessary, the leveling wedges under the machine base hold the machine in proper position until after the grout has been poured.

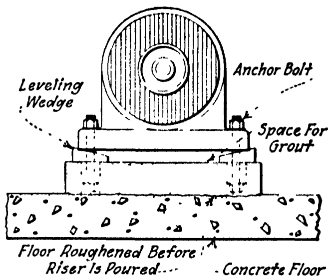


FIG. 239.—Concrete raiser.

361. A Motor Which Is To Be Belted To A Shaft Must Be Aligned With That Shaft.—That is: (1) *The shaft of the motor must be parallel to the driven shaft.* (2) *The motor pulley must be lined up with the driven pulley.* How this alignment may be obtained in installing a motor on ceiling, wall, or floor, is explained in the following sections.

362. The Cut-And-Try Method Of Aligning An Assembled Belted Machine, When Both The Driven And Driving Pulleys Have The Same Face Width, is illustrated in Fig. 240. A line, *AB*, is made parallel to the rim of the pulley which is not on the machine and then the machine is shifted until its pulley is parallel to this line. If a wooden raiser is employed, the machine should, preferably, be mounted on it while it is being aligned. If a concrete raiser is used, the machine may be carried on the leveling wedges while it is being aligned, or instead it may first be aligned on the concrete surface and the wedges inserted later to raise and level the machine to its exact operating position.

363. EXPLANATION.—A nail, *A*, is driven back of the line-shaft pulley. A line is tied to *A* and stretched; it is held at its lower end by the hand of

an assistant near point B at the floor. The erector inserts a spacer (a thin piece of wood) at D between the line and the pulley rim. The cord tension holds the spacer in this position. The assistant then moves the B end of the taut cord transversely until it lies exactly parallel with the edge of the line-shaft pulley. That is, he moves the B end until the distance D_1 exactly equals the distance D. This is determined by a

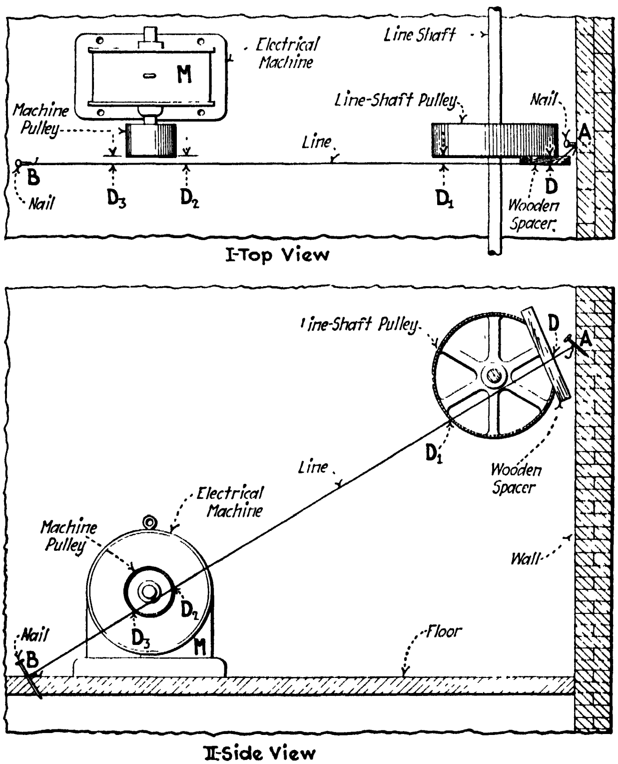


FIG. 240.—Cut-and-try method of ranging a self-contained belted machine when both the driven and driving pulleys have the same face width.

piece of wood, of the same thickness as that used for the spacer at D, being inserted at D_1, by the erector, between the pulley rim and the line.

The line AB should now be in such a position that the spacer will just slip between the pulley rim and the cord at D_1. The line AB, now having been made parallel with the pulley rim, is held in this position by the assistant or is fixed in this position by tying it to a properly located nail at B. Now the machine M is shifted until the distances D_2 and D_3 are the same as D_1 and D, as determined by using the same spacer as that employed in providing the proper spacing at D_1.

364. Sometimes Small Belted Rotational Machines Are Aligned With The Line Bearing Directly Against The Pulley Rims.—Figure 241 shows the first step; the line bears at *A* and *B*, against the rim of the pulley with which the motor

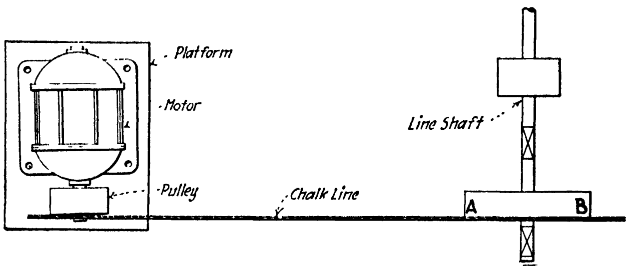


FIG. 241.—The line bears against the line shaft pulley at *A* and *B*.

must align. The line is held in this position. Then the motor is shifted until its pulley just touches, at *C* and *D*, Fig. 242, the line at the two pulley edges. Figure 243 shows the side view of this operation.

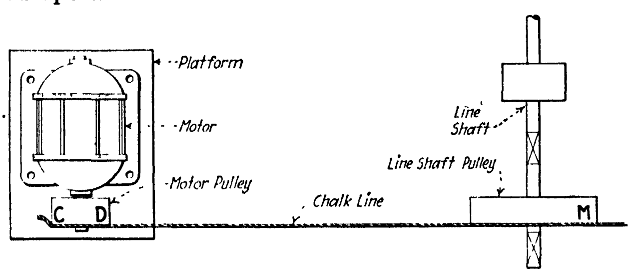


FIG. 242.—Motor shifted until its pulley bears against the line at *C* and *D*; *MC* is the reference line.

365. NOTE.—A METHOD, USING PLUMB BOBS, WHEREBY ONE MAN MAY ALIGN A BELTED MACHINE Is illustrated in Fig. 244. Two men are ordinarily required in applying the methods of Figs. 240, 241, 242 and 243, particularly if the distance between the driving and the driven pulleys is great. But with this method of Fig. 244 one man can readily do the work. Two plumb bobs and lines are necessary. First, both of the bobs, *A* and *B*, are dropped down to almost touch the floor. Then another line, *EF*, is stretched across the floor—or a chalk-line line is struck—so that it passes accurately under the points of *A* and *B*. This line, *EF*, will be at right angles to the line shaft. Then the plumb bobs are moved over to the motor location. They are dropped down so that

their points, C and D, lie over line EF. Then the motor is shifted until its pulley rim just touches the drop lines which support C and D.

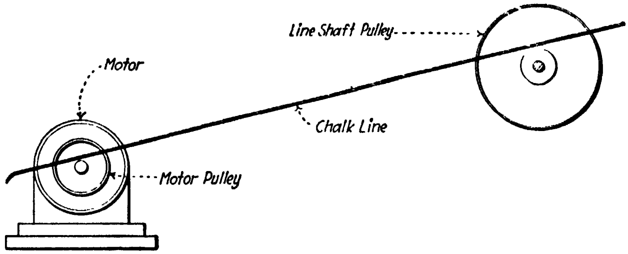


FIG. 243.—Side view; the line is bearing against edges of the lineshaft pulley

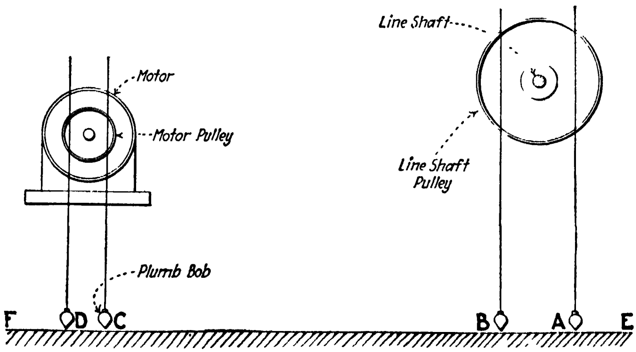


FIG. 244.—Method whereby one man may align a belted machine.

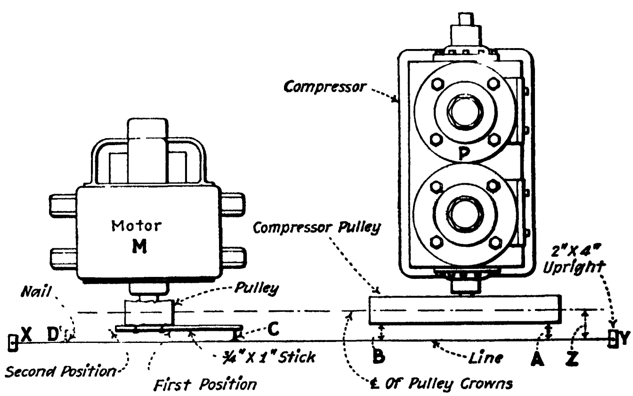


FIG. 245.—Aligning a machine which has a pulley with irregular edges.

366. A Method Of Aligning A Machine Which Has A Pulley With Irregular Edges is illustrated in Fig. 245. A batten is

secured on the end of the pulley. A nail, which serves as a gage pin, is driven in the outer end of the batten. By shifting the motor, adjust the nail head to the reference line at one side, and then similarly adjust it at the diametrically opposite side. Thus, the alignment of the machine is obtained. The method will be explained by an illustrative example which was contributed to *Power Plant Engineering* for Nov. 15, 1922, by August Gass.

367. EXPLANATION.—It is desired to align the motor M (Fig. 245) with the air compressor P. The pulley of the motor is of paper and, due to its having been left out in the weather, has very irregular edges. The

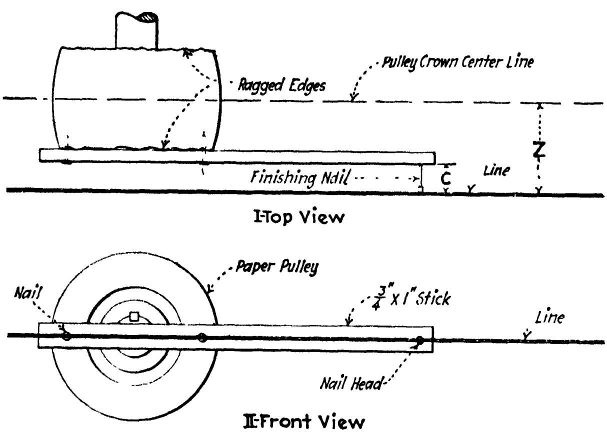


FIG. 246.—Details of aligning rig for a pulley which has irregular edges.

procedure is as follows: Erect a 2- × 4-in. upright at Y and a similar one at X. Cut a saw groove in each at such a height that a line (cord or wire) XY, drawn between the two saw cuts, will pass in front of the shaft-centers of both the compressor and the motor. Gage the distance A and shift the reference line at X until the distance B exactly equals A. Then, XY will be at right angles to the shaft of the compressor.

Next, determine the distance Z from the center of the pulley crown to reference line XY. Now attach a batten to the motor pulley (Fig. 246). This may be a ¾- × 1-in. stick. In the outer end of this batten drive a nail so that its head will be the distance Z from the pulley-crown center line. Now adjust the position of the motor so that, with the batten in position C (Fig. 245), the head of the nail will just clear the reference line. Turn the shaft through one-half a revolution, bringing the batten into position D. Again shift the motor until the nail head in

this position just clears the reference line. Continue rotating the batten from *C* to *D*, and shifting the motor as necessary, until the nail just clears the line at both *C* and *D*. When this condition obtains the motor will be aligned.

368. A T-Square May Be Used For Aligning Small- And Medium-Capacity Belted Machines.—Such a T-square (Fig.

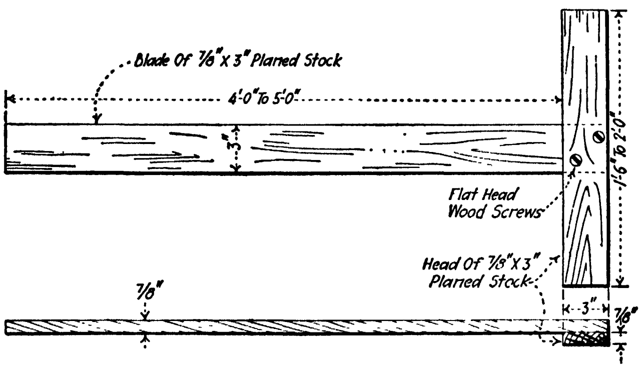


FIG. 247.—T-square for aligning electrical machinery.

247) is of special construction and must therefore be made on the job. The constructional details are shown in the illustration. In using this T-square, the edge of its head is lined

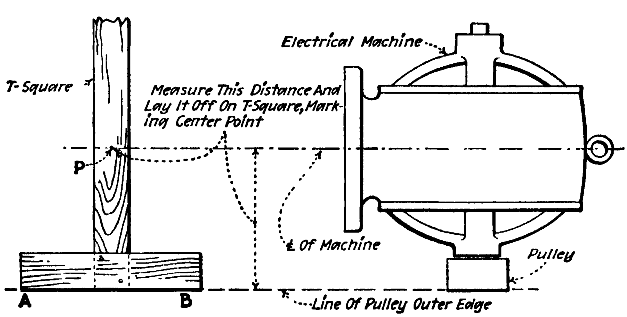


FIG. 248.—Marking the electrical-machine center-line location on the T-square blade.

with the reference line (Figs. 248 and 249), which places its blade at right angles to the reference line. Then, the center line of the machine and anchor-bolt locations can be established

accurately by measuring on the T-square blade.[1] Its application is explained in the following examples.

369. EXAMPLE.—TO USE THE T-SQUARE TO ALIGN TWO PULLEYS WHICH HAVE THE SAME FACE WIDTH: Place the T-square against the machine (Fig. 248) with the outer edge, *AB*, of its blade in line with the outer edge of the machine pulley. Now mark, on the blade, the point, *P*, opposite the center of the motor. Stretch a reference line (such as *MC* in Fig. 242) just touching the edges of the pulley with which the machine pulley is to be aligned. Place the T-square, at the location at which the machine is to be installed, so that the outer edge *AB* of its blade just touches the reference line. Then the mark *P* on its blade

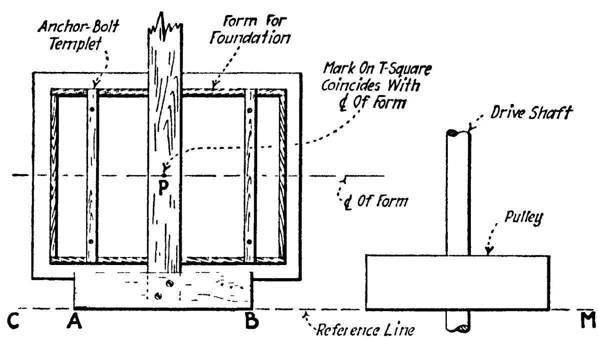


FIG. 249.—Establishing the center line of a motor foundation with the T-square.

will indicate the location of the motor center line. From this motor-center-line location the exact locations of the machine anchor bolts may readily be determined.

370. EXAMPLE.—TO USE THE T-SQUARE TO ALIGN TWO PULLEYS WHICH HAVE DIFFERENT FACE WIDTHS: If the face of the other pulley is wider than that of the machine pulley, locate the point *P* (Fig. 248) a certain distance to one side of the machine center-line location. This distance should be equal to one-half the difference between the face widths of the two pulleys. Otherwise the procedure is the same as that outlined in the preceding example.

371. EXAMPLE.—TO USE THE T-SQUARE TO ALIGN A FORM FOR A CONCRETE FOUNDATION: The reference line *MC* (Fig. 249) is stretched. The wooden form for the foundation is placed in approximately its final position. The T-square is then placed on top of the form. The edge *AB* of the T-square blade is adjusted to touch the reference line; the point *P*, which has previously been located on the T-square blade, as explained above, will indicate the location of the foundation-form

[1] JENSEN, J. *Industrial Engineer* for June, 1922.

center line. Now the form is shifted until its center line lies just under P and is parallel to MC. The form is secured in this position and the concrete poured.

If the machine pulley location is higher or lower than that of the other pulley, the T-square should be tilted on the top of the form by inserting a wedge at each of its ends between the form top and its blade. By thus tilting the T-square, the edge AB of its head may be made to touch the reference line for its full length.

372. After Having Been Aligned, The Machine Is Leveled. If a raiser (Sec. 360) has been employed, the machine base should rest on the raiser (or wedges) at correct elevation. Then it is carefully leveled (See 389) by inserting shims under its base or adjusting the leveling wedges, as necessary. This having been done, the locations of the anchor bolts should be marked on the supporting surface, using the machine base as a templet. The anchor-bolt locations having been thus marked, the machine is removed, the anchor-bolt holes drilled, and the anchor bolts inserted. After the insertion of the bolts, the machine may be replaced and the nuts tightened. Then it should be checked for elevation, alignment, and level. If these are correct the machine should be ready for operation.

373. The Measurement Method Of Locating Belted Machines will now be described. The "measurement method" is defined in Sec. 354 and its application is explained in Sec. 356. The following description of the measurement method is based on that "Lining Up A Motor For Shafting Or Machine Drive," by K. A. Reed, and published in *Power* for Sept. 21, 1920.

374. NOTE.—IN THE MEASUREMENT METHOD THE ANCHOR BOLTS, OR THE HOLES FOR THE ANCHOR BOLTS, DETERMINE THE ALIGNMENT OF THE MOTOR.—Also the anchor bolts, or the holes for the anchor bolts, must be so located that they will fit the holes in the motor feet or guide rails. These locations must ordinarily be determined before the motor is in place. Consequently, the anchor-bolt locations must be determined from measurements (Sec. 356).

375. Those Dimensions Of A Motor Which Are Necessary For Correct Location Of The Anchor Bolts In The Measurement Method are (Fig. 250) D, E, W, T, J and M. For the purpose of determining whether or not the motor will clear columns, beams, and the like, the dimensions H, B, and F

will usually be sufficient. Ordinarily these dimensions can be obtained from the manufacturer of the motor. Usually the local district office of any motor manufacturing concern will furnish gratis a *Dimension Leaflet*, for any motor which it manufactures, which will give complete dimensional information concerning that motor. However, if for any reason the dimension leaflet for a motor cannot be obtained from its

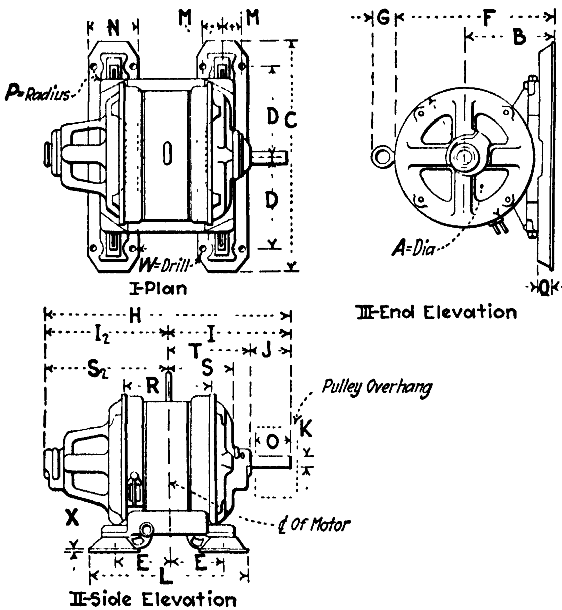


FIG. 250.—Showing the principal dimensions of a motor which are usually given on the manufacturers' dimension data sheet.

manufacturer, the necessary dimensions can be accurately taken from the motor. Convenient methods for determining such dimensions from the motor itself are described in the following note.

376. NOTE.—THE DIMENSIONS WHICH ARE NECESSARY TO SECURE PROPER ALIGNMENT OF THE MOTOR AND WHICH MUST BE DETERMINED BY MEASUREMENT are as outlined above, *D*, *E*, *W*, *T*, *J*, and *M*, and the pulley overhang (Fig. 250). How the necessary measurements may be taken to determine each of these dimensions is outlined below,

Dimension D (Fig. 250) is the projected distance from the center of the shaft to the center of the bolt holes in the slide rails when the motor is exactly half-way between surfaced parts of the slide rails. To obtain *D*, measure the distance between the anchor-bolt holes (Fig. 251) and divide it by 2.

Dimension E (Fig. 250) may be determined by turning the motor up on its side (Fig. 252) and measuring the distance between the centers of bolt holes in the feet; then divide this distance by 2.

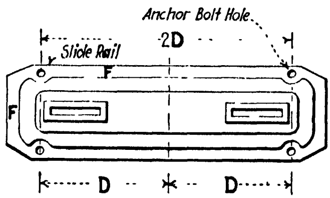


FIG. 251.—How to determine dimension *D* of Fig. 250.

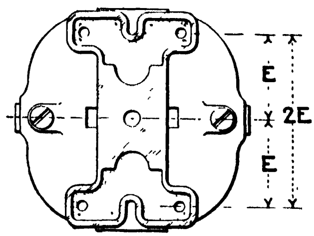


FIG. 252.—How to obtain dimension *E* of Fig. 250.

Dimension W (Fig. 250) may be determined by measuring the diameter of one of the anchor-bolt holes in one of the slide rails.

Dimension T (Fig. 250) may be obtained as shown in Fig. 253. Place the end of the scale on the center line of the eyebolt. Drop a plumb line flush with the end face of the oil well in the end bell at *X* (Fig. 253). Then read the distance from the center of the eyebolt to the plumb line.

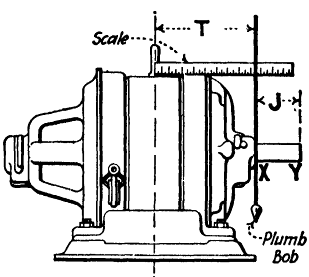


FIG. 253.—How to determine dimension *T* of Fig. 250.

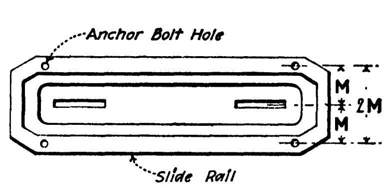


FIG. 254.—Bottom view of slide rail. Method of obtaining dimension "M" in Fig. 250.

Dimension J (Fig. 250) is obtained by measuring that portion of the shaft (Fig. 253) which projects beyond the endbell after the rotor has been set in the bearings so that one-half of the total end play is on each end of the shaft.

Dimension M (Fig. 250) can be most readily obtained by turning the slide rails upside-down and measuring (Fig. 254), in a direction parallel to the shaft, the distance between centers of the anchor-bolt holes. The

distance thus measured will be $2M$. Therefore, to get M, take one-half the distance thus measured.

The Pulley Overhang (Fig. 250) may be obtained by laying a straightedge or square (Fig. 255) across the rim of the pulley, and measuring,

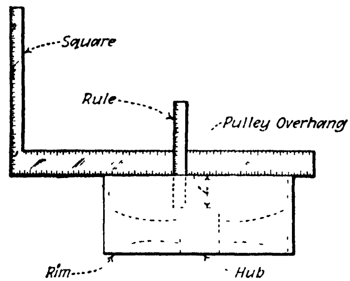


FIG. 255.—Measuring pulley overhang.

with a scale, the distance between the lower edge of the square and the end of the pulley hub.

377. To Line Up The Motor With The Line-Shaft Pulley (Fig. 256) fasten a strong cord to a support at X, back of and

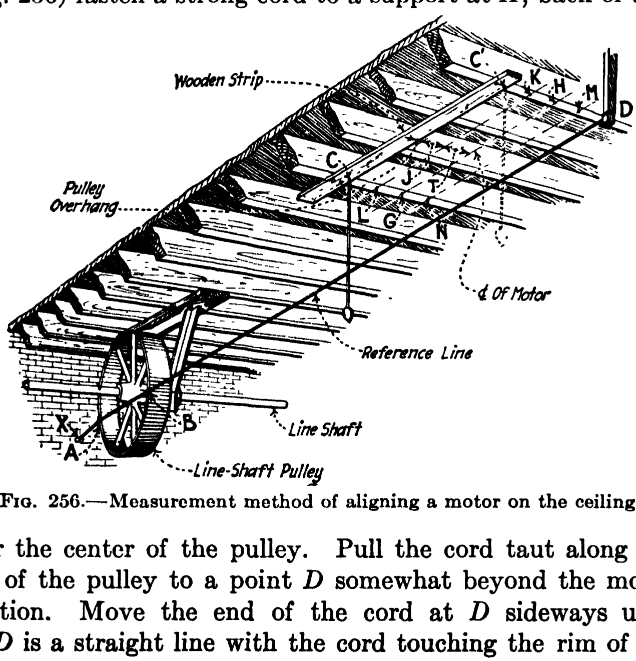


FIG. 256.—Measurement method of aligning a motor on the ceiling.

near the center of the pulley. Pull the cord taut along the rim of the pulley to a point D somewhat beyond the motor location. Move the end of the cord at D sideways until ABD is a straight line with the cord touching the rim of the

pulley at A and B. Fasten the cord to a piece of wood or a nail at D, so that it will be secure and not likely to move. The two points C and C' can be located on the ceiling by means of a plumb bob as indicated. If the motor is to be installed on a floor or wall, CC' can be located in a similar manner. After locating the line CC' it is desirable to nail, as shown, a small, straight, wood strip to the ceiling, so that the straight edge of the strip will coincide CC'. This strip can then be used as a backing for a carpenter's square in locating the other points. The line CC' thus located will be perpendicular to the line shaft. It will also be vertically over the outside edge of the motor pulley. The further procedure, which is explained below, for properly locating the motor, applies particularly to a motor which is to be mounted on a joist-and-wood floor ceiling. The same principles apply if the motor is installed either on a floor or a wall.

378. NOTE.—TO LOCATE THE POSITION ON THE CEILING OF THE CENTER LINE OF THE MOTOR, use a carpenter's square and measure off a distance, from the edge of the wood strip which coincides with CC', equal to: *pulley overhang* $+ J + T =$ (See Fig. 250 and 256). This will establish line HG (Fig. 256). By laying off on each side of line HG a distance equal to E, Fig. 250, the center lines MN and KL of each guide rail are determined. Now secure the wooden stringers (Fig. 149) to the ceiling so that the center line of each stringer coincides with MN and KL. Now, by using dimension E, M, and D, (Fig. 250), the place to bore the guide-rail, anchor-bolt holes in these stringers can be determined. If the dimensions are accurately laid out, the motor pulley will be in line with the line-shaft pulley and the line shaft and the motor shaft will be parallel. The guide rails should be level. This leveling can be effected by shims placed between the guide rails and the stringers.

379. In Aligning A Motor On A Concrete Foundation, a templet should be constructed from the dimensions so that the anchor bolts, when held in the concrete by the templet, will fit into the guide rails or into the motor feet. The alignment is then effected by making the center line of the templet coincide with the motor center line, which has been determined as explained above. See the author's "Machinery Foundations And Erection."

380. The T-Square May Often Be Used To Advantage In Locating Machines By The Measurement Method.—The use of this tool (Fig. 247) has already been described, in con-

nection with Figs. 248 and 249, as it is employed in cut-and-try location. When using the T-square for measurement location, additional lines may be drawn on its blade, indicating the anchor-bolt locations; then these lines may be transferred to the foundation, ceiling, or other support. In using the tool for a ceiling location, the edge *AB* (Fig. 248) may be placed against the wooden strip (Fig. 256) which is nailed to the ceiling.

381. NOTE.—THE T-SQUARE MAY ALSO BE EMPLOYED TO ESTABLISH A REFERENCE LINE AT RIGHT ANGLES TO A LINE SHAFT (Fig. 257), when there is no pulley on the line shaft. The T-square blade is held against the surface of the shaft; the edge of its head will establish a line at right angles to the shaft.

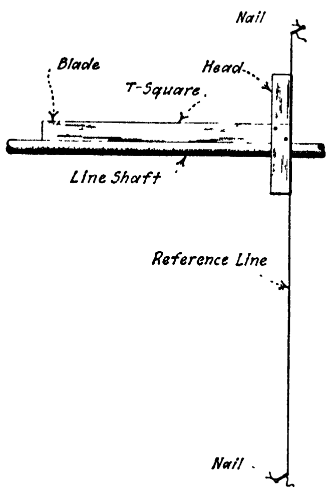


FIG. 257.—Using the T-square for establishing a reference line at right angles to a line shaft.

382. After A Rotational Machine Which Was Shipped Assembled Has Been Aligned "It Should Be Fixed" to its support. As defined in preceding Sec. 321, fixing means the securing of the machine in the exact operating position which it should occupy. When the machine is sustained on a timber support, the tightening of the nuts on the anchor bolts which secure it, constitutes the fixing process. But where the machine is supported on a concrete surface or on a concrete foundation, it should, ordinarily, be grouted in its final position. The grouting process, and the leveling of the bedplate with wedges which precedes it, will now be described.

383. Bedplates Are Really Only Liners Or Templets.—This applies particularly to the bedplates for the larger machines. Their function is to locate the elements of the machine in correct relation and to provide means for fastening these elements to their true support, which is the foundation. Checking with an accurate level, a large bedplate, which is

supported only at its ends, will show how great the deflection, in the apparently massive structure, may be unless it is properly supported. Hence, even though a bedplate appears to be very strong, it is unwise to endeavor to support it without grouting it on the top of the foundation or other structure.

384. NOTE.—BEDPLATE DISTORTION WILL BE MAGNIFIED BY THE BEARING PEDESTALS due to their length. A slight distortion of the bedplate may therefore cause considerable misalignment of the bearings. Hence, the wedges under the bedplate should be spaced evenly and so located that they will support the bedplate uniformly and at a dead level.

385. NOTE.—BEDPLATES ARE GROUTED TO HOLD THEM ACCURATELY IN POSITION AND TO PREVENT DISTORTION.—Although bedplates may appear to be very strong, they are quite readily warped under load unless they are evenly supported; this applies particularly to large bedplates. Small bedplates are not, usually, thus prone to warp. But in any event the grout under any bedplate prevents the horizontal movement thereof and provides an even support under its entire outline.

386. Prior To Placing A Bedplate On A Foundation, The Foundation Should Be Prepared For Its Reception.—The area which the bedplate will occupy on the foundation top is laid out in outline, approximately. Then the portion of the foundation top included by this area is roughened so that the grout may obtain a good "grip" on it. The amount of roughening that is necessary will be determined by the characteristics of the machine. A foundation which is to support a self-contained unit such as a frequency changer, a synchronous converter, or a motor generator, need not have as secure a bond between the grout and the foundation top as should one which is to carry a unit which will deliver or receive power by means of a belt or shaft. A small amount of roughening will suffice for the self-contained machines. But in any case sufficient concrete should be removed from the foundation top so that the layer of grout may be from ¾ in. to 1 in. thick under the flanges of the base. For the non-self-con-

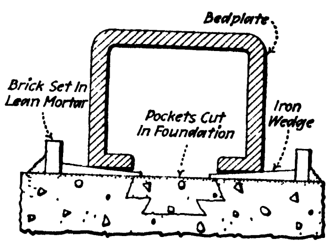


FIG. 258.—Section through bedplate set on leveling wedges.

tained machines the rougher the surface the better. For such machines, some erectors cut pockets (Fig. 258) in the foundation top to provide a "lock" for the grout. However, such procedure is seldom necessary if the foundation top is reasonably rough and clean.

387. NOTE.—AFTER ROUGHENING THE FOUNDATION TOP, IT SHOULD BE CLEANED.—All dust and concrete particles should be removed from the pockets. A stiff brush or compressed air, under low pressure, may be employed. If the dust which is produced thereby would be objectionable, compressed air should not be employed.

388. Prior To Grouting, A Bedplate Must Be Adjusted Accurately To Its Final Position.—That is, it must be arranged and leveled as hereinbefore suggested. The leveling is executed by arranging wedges under the bedplate.

389. Each Bedplate Should Be Carefully Leveled In Both Directions by using an accurate level and straight edge on the machined surfaces by the process which is described in preceding Sec. 372. The bedplate is brought to the level plane by adjusting wedges under it. The wedges should be adjusted by increments to prevent any wedge from carrying too much of the total load; this would tend to distort the bedplate.

390. NOTE.—WEDGES SHOULD BE PLACED AT EACH ANCHOR BOLT (Fig. 258) if anchor bolts are employed. After the bedplate has been aligned and leveled, the nuts on all of the anchor bolts should, prior to grouting, be set tight onto the bedplate which will bind the bedplate securely in place against the wedges.

391. The Planed Surface On A Bedplate May Be Utilized In Leveling It.—If there are finished pads on the upper surface of the bedplate for supporting the bearing pedestals, the level may be placed on these pads as suggested by Fig. 231. If there are no planed surfaces available, on the top face of the bedplate, planed surfaces on its under face may be employed; a piece of cold-rolled steel placed under the bedplate and wedged up against the planed surface can be used as a support for the straightedge and spirit level.

392. Wedges For Leveling Bedplates (Fig. 259) may be used either singly or in pairs. When used in pairs, the two wedges offer a flat surface to the bedplate and thereby afford

more bearing surface. The number of wedges which should be employed will be determined somewhat on the size of the bedplate which is to be supported. In general, wedges should be spaced not to exceed 4 ft. apart around the edge of the bedplate. But in any event there should be a wedge adjacent to every anchor bolt (some erectors place wedges on both sides of each anchor bolt). The wedges should always be spaced, approximately, equidistantly around the bedplate. The wedges should always be of sufficient height to maintain the bottom edge of the bedplate from $\frac{3}{4}$ in. for the smaller machines up to $1\frac{1}{2}$ in. for the larger machines above the foundation top; this is to allow for grouting.

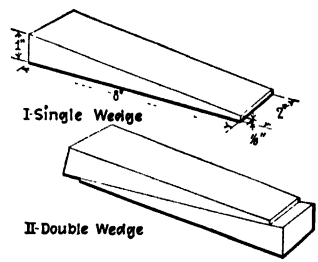


FIG. 259.—Iron leveling wedges made for 1 in. by 2 in. bar-iron stock.

393. NOTE.—SOME ERECTORS PERMIT THE WEDGES TO REMAIN UNDER THE BEDPLATE after the grout has set. However, in general, it appears to be safer to remove the wedges after the grout has partially set. If the wedges are left in place and the grout should shrink away from the bedplate, the wedges would carry the load and strains may be set up in the bedplate which would distort it. While it is certain that in many cases wedges left under bedplates have not given trouble, there are other recorded cases where wedges thus left have been thought to have caused trouble. Hence the safer procedure is to remove the wedges.

394. For Wedge Material iron is the most desirable, although hard wood wedges are sometimes employed for light machinery. Cast-iron wedges are frequently employed but because of their brittleness they are undesirable. For the average installation wedges made from 1-in. × 2-in. bar-iron stock (Fig. 259) is very satisfactory. These exact dimensions need not be followed if others are more adaptable for the job under consideration.

395. After A Machine Which Is Shipped Assembled Has Been Located, Aligned, And Leveled With Wedges On Its Support, The Bearing Alignment Should Be Checked.—For sets which have three or more bearings, this is best done by

backing off the coupling bolts slightly and rotating the machine by hand. If the two shafts are out of line, the coupling halves will separate. The separation between the halves will indicate the direction in which the alignment must be adjusted. Each coupling face should be true and at right angles with the center line of its shaft before an endeavor is made to align the two machines. The air gap is adjusted by means of shims under the magnet-frame feet and under the pillow blocks. With a three-bearing machine, great care must be observed to insure that the bedplate is not sprung; if it is, the bearings will be thrown out of alignment. For a large machine, the deflection of its heavy shaft may necessitate shimming up the end-bearing pedestals above their apparently correct locations to bring the coupling faces into parallelism. Misalignment of coupling may cause it to "work" on the shaft even though the bearings show no distress. If all alignments are found to be, or are made to be correct, then the bedplate is ready for grouting.

396. NOTE.—THE BOLTS OF A COUPLING SHOULD NOT BE USED TO FORCE ITS TWO HALVES TOGETHER, unless the coupling faces lie accurately parallel with one another. The coupling bolts are intended merely to do the rotational driving of the unit; they are not provided for forcing the two components of the unit into apparent alignment.

397. NOTE.—FLEXIBLE COUPLINGS SHOULD NOT BE DEPENDED UPON TO CORRECT MISALIGNMENT.—Such couplings should be checked as carefully for parallelism as are rigid couplings. Misalignment of flexible couplings will cause excessive wear in them and may be responsible for other damage.

398. The First Step In Grouting Is To Build Dams For Retaining The Grout (Fig. 260).—These dams should always be constructed entirely around the outside of the bedplate. Often, with large bedplates, grout may be saved by placing dams on both the inside and the outside. Structural-steel bases or soleplates are grouted full; the dams for these should be as high as they are. Cast-iron bedplates are seldom grouted more than ¼ in. to ½ in. above the bottom of the lip inside the base; the dams for these need not be higher than 1 in. above the bottom of the base. Deep grouting, due to the difficulty of its subsequent removal, is not recom-

mended. Boards, which are held in position with bricks, stones, clay, or mortar, are often used as dams. Sand, clay, or mortar, distributed along the edges of these dam boards, which rest against the foundation top, will prevent the grout from flowing out at this juncture. Bricks, laid with a lean mortar, also make a cheap and satisfactory dam. The bricks can be removed after the grout has set, cleaned readily, and put back in stock.

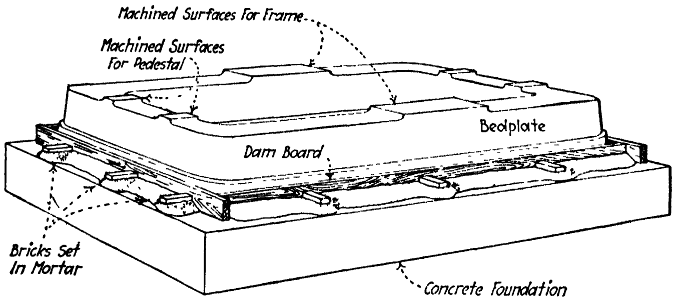


FIG. 260—Dam boards arranged around a bedplate.

399. NOTE.—DAMS SHOULD BE CONSTRUCTED AS CLOSE TO THE OUTLINE OF THE BEDPLATE as is possible. When the outline is regular and no wedges project outside, the dam can be built immediately against the bedplate. When the bedplate is irregular or the wedges project on the outside, then the dam must be erected at a small distance from the bedplate.

400. The Composition Of Grout is ordinarily a mixture of one part of portland cement and one part of sand. In some instances a mixture of one part of cement and two parts of sand has been employed with satisfactory results. The cement and sand are first mixed dry. Then, water is added until a relatively thin solution is obtained. The mixture should be sufficiently thin so that it may be puddled thoroughly under the base. In consistency it should be about like thick porridge. If it is too thin, it requires longer to set and to harden sufficiently to "hold." Grout should always be kept clean; foreign substances greatly weaken it. Before pouring the grout, it is always desirable to clean and wet the foundation top. This insures a better bond between the foundation and the cement.

401. NOTE.—THE ENTIRE OPERATION OF MIXING AND POURING THE GROUT SHOULD BE COMPLETED WITHOUT INTERRUPTION and as rapidly as possible. Otherwise, the cement which is first poured under the bedplate may partially set and prevent that which is poured later from flowing freely to all parts.

402. NOTE.—VARIOUS METHODS OF PLACING AND INJECTING GROUT UNDER MACHINERY BEDPLATES are described in the author's "Machinery Foundations and Erection."

403. NOTE.—FOR LARGE BEDPLATES FOR WHICH A GREAT AMOUNT OF GROUT IS REQUIRED, OLD CEMENT MAY BE ADVISABLE.—It sets more slowly and with less temperature rise than new cement; and the temperature rise, if excessive, might cause distortion of the base due to expansion.

404. NOTE.—OTHER GROUTING SUBSTANCES, SUCH AS SULPHUR, are sometimes used, but they are not as satisfactory as cement grout. The preparation and use of such materials are described in the author's "Machinery Foundations and Erection."

405. After The Grout Has Become Solid, The Surplus Can Be Trimmed Away from the outside of the bedplate. Then, when the grout has hardened, (which usually requires from 3 days to a week, depending on its depth and the age of the cement), the operation or the assembly of the machine can proceed. The wedges should be removed after the grout is hardened, and the spaces which they occupied tamped full of sand-and-cement concrete.

406. Some Practical Suggestions On Grouting are the following.[1] These summarize the many years' experience of one practical man in relation to this operation:

407. THE IDEA OF USING LEVELING PLATES, which are set and grouted before the bedplate is lowered thereon, is all right when the base is machined in the shop. However, if the bedplate is a rough casting, I prefer wedges of wrought iron about 6 in. long and tapering from $\frac{1}{2}$ in. to a point, and of a width anywhere from $1\frac{1}{4}$ to $2\frac{1}{2}$ in.

408. THE PURPOSE OF GROUTING under a piece of machinery is to provide a substantial foundation for the machine. It cannot be done with certainty of success by damming up the grouting space at the edge of the base and pouring the cement into this space from the inside or other convenient opening at a later time. If this is done there is no means of knowing whether or not the grouting has filled up the space. Also, if this method is used there is no way for the air to get out, which is quite important with some forms of grouting, nor is there provision for the surplus water to work to the top. I believe that good work cannot be done by this method, especially where the area covered is large.

[1] WALLACE, GEORGE H., *Power*, Feb. 13, 1923, on p. 262.

409. The Writer Has Always Grouted From The Outside, or at least placed the dam several inches outside of the base, whether the grouting is poured from outside or inside.

410. The Manner Of Building The Dam depends a great deal on the material at hand. Common brick laid flatways, two high, in common lime mortar about 6 in. from the base provides a good dam. These bricks can be knocked loose, the next day after grouting, and the mortar easily scraped from them. Boards, say 4 in. wide, set on edge and formed about the base as required and suitably braced or weighted at intervals, are much used. Where the floor is irregular, they can be backed up with sand or gravel to prevent leakage.

411. The Grouting Should Be Poured In As Rapidly As Possible and worked inside with something flexible, such as hoop iron, willow switches, perforated strap iron, or the like, until the movement of such roweling on one side is noticeable on the other side of the base, if it is not over 6 or 8 ft. wide. Pouring and grouting should continue until the cement is well worked in all around, and stands about 1 in. at least above the bottom of the casting. Seeing this on the outside insures for a certainty that the grout has been forced up into all the channels of the base and into the irregularities of the casting.

412. After Grouting Has Set About 8 To 10 Hours It Can Be Cut Along The Edge Of The Bedplate if desired, with a common trowel or similar tool, and later on in the course of 36 hours or so, this surplus can be removed. This leaves a good job of cementing.

413. As To The Proportions Of Sand And Cement, this is a matter that requires good judgment, as sand and cement differ. With good cement and sand, all that is needed is a mixture that has cement enough in it to fill all the spaces between the grains of sand. Generally, a mixture of half-and-half is too rich and is easily broken, as can be demonstrated by test blocks. The writer has found that a proportion of two parts good Portland cement and three parts clean sharp sand usually makes an ideal mixture. Even this is not a universal rule. In some localities sand is perfect and in others it is necessary to wash the sand, or remove the clay, to insure a good job.

414. The Ideal Way To Grout A Bedplate, Is To Have A Power Mixer in such a position that the mixture can be run down troughs to the several locations in quantities, so that it will be forced into all parts of the space before it has time to settle. If necessary to wheel the grouting material some distance, it should be kept thoroughly stirred while pouring. A pail, though often used, is a sloppy contrivance. It permits the thin material to run out first and leave the thick grout. It usually spatters cement, which is sometimes a great disadvantage.

415. A Good Device To Use For Pouring Grout Is A Common Scoop-Shovel.—If the grout has to be mixed by hand, locate the mixing box close by. While the material is being stirred or kept in motion, it is easily scooped up and transferred to the form without any settling.

416. Before Making The Dam, Wash The Top Of The Foundation under the bedplate with a stream of water from a hose so that all loose sand and dust will be washed out and permit good contact. Just before pouring the grout, turn in a little more water.

417. As To Leaving The Wedges Under A Machine, it is best to remove them, if possible, on general principles. Tap them sideways about the second or third day after grouting; in a week they can be withdrawn entirely. A wrought-iron wedge is preferable to a cast one, as the latter is easily broken under strain or in withdrawing. Holes in the grouting can be easily repaired. However, if the wedges cannot be withdrawn, let them remain. There are many engines and other machines running successfully setting on wedges. If the grout is well worked up into the channels of the frame or baseplate, and the cementing is thoroughly done, the machine will run indefinitely.

418. Tighten Down The Nuts On The Foundation Bolts After The Grout Has Set, say, in about a week. Do not try to stretch the bolt; it cannot be done. Draw the nuts up snug and hit the wrench a few sound cracks with a sledge. The writer has put in several engines with nothing but bruised bolts about 4 ft. long to "hold them down," if one can conceive of their moving. On one occasion, while running in a 50-per-cent-overload test for 8 hours, all of the foundation bolt nuts were loosened a few turns to satisfy an over-officious master mechanic that the engine was without vibration. A new lead pencil stood on the cylinder during the test.

419. The Processes Of Locating And Fixing Rotational Electrical Machines Which Are Shipped Disassembled Will Now Be Discussed.—All of the larger machines are included in this class. However, especial attention will be devoted to three-bearing sets such as motor-generators and frequency-changers and to turbo-generators. These require the most experience and skill for their successful erection.

420. Some Of The Larger Machines Which Are Shipped Disassembled Have Soleplates instead of bedplates (Fig. 170). Engine-type generators and synchronous motors are often of this construction. These machines are more difficult to install than those which have bedplates because each soleplate must be very carefully located; it must be accurately aligned and leveled. In building the foundation for such a machine, the anchor bolts must have been carefully located with a templet. Each soleplate should be grouted to the top of the foundation, in the same manner as a bedplate. Machines which have soleplates should ordinarily be installed by an experienced erecting engineer.

421. The Erecting, Locating, And Fixing Of A Disassembled Two- Or Three-Bearing Unit On Its Bedplate after the bedplate has been accurately aligned, leveled, and grouted (as hereinbefore described) is a comparatively simple process. All polished parts should be cleaned of the protecting grease or "dope." The journal surfaces should, if necessary, be polished with crocus cloth; any burrs or rough spots should be smoothed off with a fine file or an oilstone and coated with machine oil. For a two-bearing set, the shaft must be level

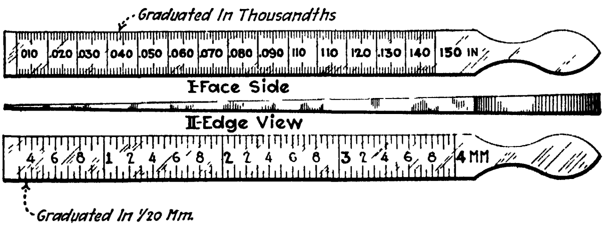


FIG. 261.—Taper thickness gage. It is made of tool steel 7/16 in. wide and 6¼ in. long. One side is graduated to read from 0.010 in. to 0.150 in. by thousandths of an inch. The reverse side is graduated to read from 0.3 mm. to 4 mm. by 1/20 mm. (L. S. STARRETT COMPANY, Athol, Mass.)

and the air gaps adjusted evenly. A taper thickness gage (Fig. 261) can often be employed to advantage in adjusting air gaps. For a three-bearing set great care must be taken to insure not only that the shaft is level but also that the bearings are accurately in line and the air gaps properly equalized.

422. NOTE.—DEFLECTIONS WHICH CAUSE TROUBLE SOMETIMES OCCUR AFTER ERECTION.—Occasionally, after a unit has been initially and accurately located and fixed, a foundation may settle or a bearing housing or a bedplate deflect sufficiently to cause shaft or bearing troubles. Even if no bearing trouble exists, shaft misalignment may produce a constant bending of the shaft which will, in time, cause fatigue and shaft breakage. Hence, every precaution should be observed to insure, by thorough and rugged initial construction, that such locating and fixing as is done will be permanent.

423. In Erecting Disassembled Machines, Which Are Provided With Bedplates, The Bedplate Is First Located And Fixed, Then The Remainder Of The Machine Is Erected On It.—After the grout under the bedplate has set, the end-bearing pedestals should be placed in position and the alignment of the bearings checked, as described in a succeeding section.

However, prior to placing the pedestals in position, the machined surfaces of the bedplate, upon which the pedestals rest, should be cleaned. Also, the bottoms of the pedestals should be cleaned. To insure correct assembly, the bearing pedestals and bedplate are, ordinarily, so marked by the manufacturer of the machine that, when correctly assembled, adjacent parts will have the same marking. Hence, care should be exercised in assembling to see that the markings of all parts correspond.

424. In Leveling The Bedplate Of A Two-Bearing Unit It Is ordinarily satisfactory to use a precision level on the spots or bosses, which have been machined on the bedplate upper surface to receive the magnet or stator frames. But on three-bearing sets more elaborate methods, as hereinafter explained, are necessary.

425. Note.—In Aligning And Fixing The Bearing Pedestals, the heights of the pillow blocks may be adjusted by inserting shims under their bases. These pillow-block heights were properly adjusted at the factory with sheet-iron or fiber shims and the shims are shipped with the machine. Usually, these shims are tied in bundles (one bundle for each pedestal) which are so marked that their proper locations on the bedplate may be identified. The shims being in place, the pillow blocks may be bolted to the bedplate. On some machines—for example, Westinghouse converters—a lateral alignment of the bearing pedestals is unnecessary in the field because this alignment was made in the factory and the pedestals were there correspondingly ream doweled to the bedplate. On other machines, lateral alignment in the field is necessary; the pedestals must be aligned and then doweled to the bedplates by drilling holes and inserting dowels in the bedplate at the correct locations. In either case, the final adjustment of the bearings themselves should be checked. It is very important that bearing alignment be correct to within a few thousandths of an inch.

426. The Line for the alignment of units which are shipped disassembled should, preferably, consist of a fine piano wire, perfectly free from any kinks or bends. It is an important precaution to see that a wire line is not distorted or bent and that it has not been wound on too small a spool. If a straight piano wire is not available, a fine silk cord or a fish line may be employed.

427. The Bedplate For A Set Which Is Shipped Disassembled And Which Has Three Or More Bearings Should Be Lined Up To A Tight Wire, prior to the placing of the other

components (with the exception of the end-bearing pedestals) of the unit on the bedplate.[1] Fig. 262 illustrates the principle. A piano wire loaded with a 30-lb. weight is stretched, accurately centered, between the two end pedestals. Then by measuring down from this wire and using the sag values which are given in Table 429, the top of the bedplate may be brought accurately parallel with the reference wire. It must, of course, be leveled simultaneously. After being thus aligned and leveled, it should be grouted and the grout permitted to set before additional elements of the set are mounted on it.

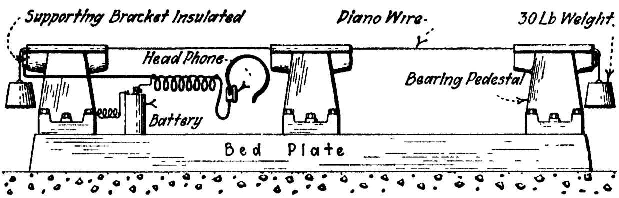


FIG. 262.—Arrangement for aligning three bearing pedestals. The battery and head telephone can be used in combination with an inside micrometer for measuring the distance between the piano wire and the bearing.

428. EXPLANATION.—A steel piano wire, 0.166 in. in diameter should be stretched over a grooved pulley which is clamped to the outer end of each end-bearing pedestal (Fig. 262). The pulleys should be approximately 3 in. in diameter. These pulleys and brackets may be of any construction which is readily available. A plain wheel or a curved segment mounted on a piece of strap iron will suffice. However, more elaborate devices which have vertical and horizontal adjustments of the wheel in the supporting bar have been employed to advantage where considerable of the work was to be done. In any case the bar which supports a pulley and the wire is fastened to the outer end of each bearing housing with a *C*-clamp. Each bar is so adjusted that the wire centers in the outer end of each bearing housing. The method of centering the wire in the bearing housing is explained hereinafter. A 30-lb. weight should be attached to each end of the wire. Then the vertical distance between this reference wire and the bedplate is measured at intervals, along the length of the wire, from the wire to some planed surface on the bedplate top. Then the bedplate is adjusted until its upper face lies level and in a true line parallel with the tight wire. To make the adjustments which are required it is necessary to employ the sag values given in Table 429, and as explained hereinafter.

[1] REA, N. L., *Power*, Dec. 26, 1922, p. 1021.

429. Table Showing Sag, In Thousandths Of An Inch, For Steel Piano Wire, 0.166 In. In Diameter, Loaded With A 30-Lb. Weight (N. L. Rea in *Power* for Dec. 26, 1922) See explanation.

Distance from supports, in feet	Distance between supports, in feet																			
	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
1	0.5	1.0	1.5	2.0	2.5	3.0	3.0	3.0	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.5	5.0	5.0	5.0	5.5
2	1.0	2.0	3.0	4.0	5.0	5.5	6.0	6.0	6.5	7.0	7.0	7.5	8.0	8.0	8.5	9.0	9.5	9.5	10.0	11.0
3	1.5	3.0	4.5	5.5	7.0	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.0	13.0	13.5	14.0	15.0	16.0
4	1.5	4.0	5.5	7.0	9.0	10.0	11.0	11.5	12.0	13.0	13.5	14.0	15.0	15.5	16.0	17.0	18.0	19.0	20.0	21.0
5	1.5	4.5	6.5	8.5	11.0	12.0	13.0	14.0	15.0	15.5	16.5	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.5	25.5
6	2.0	5.0	7.5	10.0	12.5	14.0	15.5	16.5	17.5	18.5	19.0	20.0	21.0	22.0	23.5	24.5	26.0	27.0	28.5	30.0
7	....	5.5	8.5	11.0	14.0	15.5	17.5	19.5	20.0	21.0	22.0	23.0	24.0	25.5	26.5	28.0	29.5	31.0	32.5	33.5
8	.....	....	9.0	12.0	15.0	17.0	19.0	20.5	22.0	23.5	25.0	26.0	27.0	28.5	30.0	31.5	33.0	34.5	36.0	37.5
9	.....	.....	....	13.0	16.0	18.5	20.5	22.5	24.0	26.0	27.0	28.5	30.0	31.5	33.0	34.5	36.0	38.0	39.5	41.0
10	.....	.....	.....	....	16.0	19.5	21.5	24.0	26.0	28.0	29.5	31.0	33.0	34.0	36.0	37.0	39.5	41.0	43.0	44.0
11	.....	....	...	...	....	20.0	23.0	25.5	27.5	30.0	31.5	33.5	35.0	37.0	39.0	40.5	42.0	44.0	46.0	47.5
12	.....		..	....	....	...	23.5	26.5	29.0	31.5	33.5	36.5	37.5	39.5	41.5	43.0	45.0	47.0	49.0	50.5
13								27.0	30.0	33.0	35.0	37.5	39.5	42.0	44.0	46.0	47.5	50.0	51.5	53.0
14									31.0	34.0	36.5	39.0	41.5	44.0	46.0	48.0	50.0	52.0	54.0	55.5
15										34.5	37.5	40.0	43.0	45.5	48.0	50.0	52.0	54.0	56.0	57.5
16											38.0	41.0	44.0	47.0	49.5	52.0	54.0	56.0	58.0	60.0
17											...	42.0	45.0	48.0	51.0	53.5	56.0	58.0	59.5	61.5
18											...		45.5	49.0	52.0	55.0	57.5	59.5	61.0	63.5
19														49.0	52.5	55.5	58.5	61.0	62.5	65.0
20														...	52.5	56.0	59.5	62.0	64.0	66.5
21																56.0	60.0	63.0	65.0	67.5
22																	60.0	63.0	66.0	69.0
23																	...	63.5	66.5	69.5
24																	....	.....	67.0	70.0
25																				70.5

430. NOTE.—IN USING THE SAG TABLE, locate, in its top horizontal column, the "Distance Between Supports" (for example 20 ft. Fig. 263). Then, the sag at any point along the wire will be found by locating in the vertical right-hand column the desired "Distance From Supports In Feet" and tracing across to the correct "Distance Between Supports" column. At the intersection of these two columns will be found the correct value of the sag in thousandths of an inch.

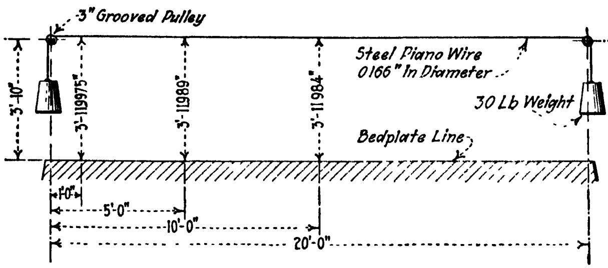


FIG. 263.—Example showing the application of the sag table.

431. The Method Of Using The Sag Table In Combination With The Tight-Wire Reference Line Arrangement is this: The reference wire will always sag somewhat regardless of how tightly it is stretched. To permit correcting for this sag, a certain kind of wire must be employed, the sag of which, under a given tension, has been determined. This tension must then always be used. In Table 429 are given the sags for a steel piano wire 0.166 in. in diameter stretched with a 30-lb. weight. These values are interpolated from a graph that was plotted from experimental results. The use of the sag table may be understood from the following example.

432. EXAMPLE.—In Fig. 263 the supports are 20 ft. apart. The wire midway between supports, that is 10 ft. from each support, will sag (see Table 429) 0.016 in. Hence if the wire at the supports is 4 ft. from the bedplate, then midway between supports it will be: 4 *ft.* − 0.016 in. = 3 ft., 11.984 *in.* (Fig. 263), when the bedplate top is a straight line between the supports. Other values are given in Fig. 263.

433. The Bedplate Should Be Grouted, After It Has Been Properly Aligned And Leveled.—The methods of grouting the bedplate for a machine, which is shipped disassembled, are substantially the same as those for the grouting of assembled-machine bedplates, which are described in preceding sections.

The grout should be permitted to "set" thoroughly before the machine components are assembled on it.

434. An Electrical Method Of Calipering The Distance Between The Inside Of A Bearing And The Steel Reference Wire is diagramed in Fig. 262. The supporting brackets, for the grooved pulleys, should be insulated from the bearing pedestals by leather board or fiber sheets. A battery and head telephone are then connected in series between the steel reference wire and the bedplate. An inside micrometer can be used for measuring between the wire and the inside circumference of the bearing shell. The micrometer is adjusted until it is of just the right length that the telephone clicks, when the micrometer ends contact respectively with the steel reference wire and the bearing shell. This method is rapid and accurate. It eliminates the element of "touch." It is particularly effective where the lighting is poor.

435. Note.—A Measuring Pin Of Steel Or Wood, With A Needle Set In Each End, May Be Employed For Centering A Bearing Around A Steel Reference Wire.—Fig. 264 shows such a measuring pin employed for aligning a shaft with a steel reference wire. For accurate work, fine needles set in the ends of the stick (the senses of both sight and touch being employed for determining contact) will give accurate results. The needles must be driven into the pin ends until the measuring pin will just pass between the reference wire and the bearing shell. The overall length of the pin, from needle end to needle end, can be measured with a micrometer. This measuring pin method is not as rapid nor as accurate as that, just described, which employs the telephone receiver.

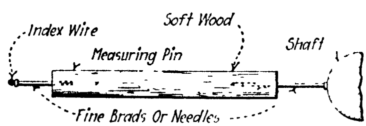


Fig. 264.—Measuring pin and its use.

436. In Locating On Their Bedplate The Elements Of A Unit, The Frame For Which Was Shipped In Halves, the lower half of the frame should be placed on the bedplate after the bearing pedestals have been fixed in position. But before placing the lower half of the frame in position, the machined surfaces on the bedplate, upon which the frame is to rest, should be thoroughly cleaned of all protecting grease Most manufacturers place an identifying mark on the frame feet and on adjacent portions of the bedplate. The unit should be

assembled accordingly. The Westinghouse Co. uses consecutive numbers for these symbols; adjacent parts bear the same number. The frame is usually adjusted to correct height at the factory by inserting shims under its feet. These shims are shipped with the machine; when they are shipped in one bundle, one-half of them should be placed under each frame foot. When two bundles are shipped, they are so marked that their proper locations can be identified. The shims being in place, and the air gap adjusted, the frame should be bolted down.

437. NOTE.—THE LATERAL ADJUSTMENT OF THE FRAME ON THE BEDPLATE is, for some machines (for example Westinghouse self-contained converters) made at the factory; the frame feet are ream doweled to the bedplate. Hence, for these, lateral adjustment when installing them in the field is unnecessary. For other Westinghouse and for all General Electric machines, the frame should be bolted down—but not doweled—until the air gap has been adjusted because, for these, the adjustment was not made at the factory.

438. Some General Instructions For The Locating And Fixing Of Electrical Machinery Which Is Shipped Disassembled are given in the following material from *Power Plant Engineering* for Oct. 15, 1924. While these data relate particularly to engine-driven units, certain suggestions which they offer may be applied to units of any type.

439. NOTE.—MOST COMMON AMONG THE CAUSES OF UNSATISFACTORY MACHINERY PERFORMANCE IS MISALIGNMENT.—The results of poor alignment do not vary greatly, except that they become more aggravated the longer the misalignment continues. These results are vibration, burned-out bearings, bent shafts, and crystallization of material in the revolving elements. All may result in breakage of shafts, couplings, and other rotating parts. Such breakages often occur when the stresses in these parts appear to be negligible. No amount of overhauling or of renewal of parts of a machine which is out of alignment and giving trouble, will remove the difficulty. The only solution is to correct the misalignment.

440. When A Machine Is In Correct Alignment Any Two Shafts Which Are Coupled Together Have Their Axes In The Same Straight Line.—Secondarily casings, cylinders, frames, and bearing pedestals are so placed that the correct clearances are obtained between them and the reciprocating parts, revolv-

ing shaft and rotor parts. All units which are completely assembled at the factory are there correctly aligned when assembled and tested before shipment. Also, the majority of such units have all parts mounted either upon a continuous one-piece baseplate or upon a two-piece baseplate the sections of which are rigidly bolted together.

441. NOTE.—NOTWITHSTANDING CAREFUL ASSEMBLY OF THE PARTS AT THE FACTORY AND THE USE OF CONTINUANCE BASEPLATES, IT IS ALWAYS DESIRABLE TO REALIGN THE UNIT AFTER PLACING IT ON THE PURCHASER'S FOUNDATION.—This is because of the flexibility of even the most massive of cast-iron baseplates and also because of the impossibility of exactly duplicating, on the customer's foundation, the conditions which obtained during the assembly and test at the factory.

442. The Simplest And Most Accurate Means Of Aligning Two Shafts, So That Their Axes Will Come In The Same Straight Line, Is That Method Which Employs The Coupling Flanges.—Remove the upper half of the coupling housing

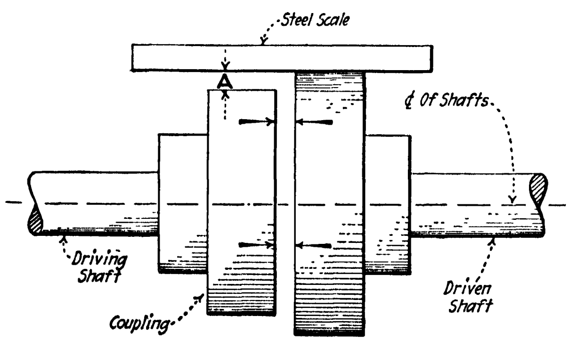
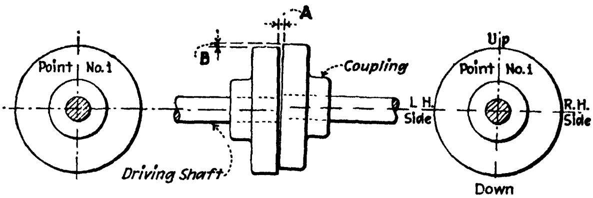


FIG. 265.—Where the coupling flanges have different diameters, the distance *A* must be measured, at a number of locations around the circumference.

or guard and take out all the coupling pins. With a short steel straightedge, which is placed across the top of the two coupling flanges (Figs. 265 and 266) the approximate difference in level of the two shafts may be observed. Likewise, by moving the straightedge down to the sides of the coupling, the approximate amount of movement necessary to bring the shafts into horizontal alignment sidewise may be observed.

443. NOTE.—THE ANGULARITY OF THE TWO SHAFTS MAY BE JUDGED WITH A TAPERED THICKNESS GAGE (Fig. 267) or a set of common feelers, inserted between the faces of the coupling flanges at various points around the circumference. Insert or remove shims from different parts of the unit, at the same time making the required sidewise adjustments, so as to bring the faces of the two coupling flanges equidistant at all points, as measured by the thickness gage, and so as to bring the circumferences of the two flanges in line at the top, sides, and bottom as measured by the straightedge.



Distance "A" At Point No. 1 For Both Shafts Turned Over Together To Varying Positions		Distance "B" At Point No. 1 For Both Shafts Turned Over Together To Varying Positions	
Up	0.124	Up	0.008
R H Side	0.124	R.H. Side	0.008
Down	0.124	Down	0.008
L H Side	0.124	L.H. Side	0.008

FIG. 266.—Final check on alignment made by rotating both coupling halves.

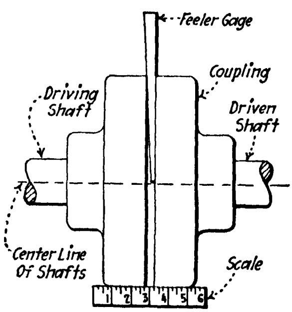


FIG. 267.—Method of testing the preliminary alignment.

444. The Preceding Alignment Is Preliminary Only And Inaccurate in that it does not recognize the possibility of the coupling faces not being machined at right angles to the axes of their respective shafts. Also, it disregards the possibility of the outside circumference of the coupling flange being turned eccentric to the axle of its shaft.

445. NOTE.—AFTER ALIGNING ROUGHLY, CONNECT UP THE STEAM AND EXHAUST PIPING, if any, (the method of rough aligning is described

in a preceding section), warm the unit, and operate it sufficiently to insure that actual and constant operating conditions have been attained. The final alignment must, as will be described, be made when the entire installation is subjected to actual operating temperatures.

446. To Align The Unit Accurately (it having been warmed and operated as hereinbefore suggested), proceed thus: Shut it down. Insert one coupling bolt without its bushing, to insure that both shafts will rotate together and always in the same relation. Mark some point, for identification, on the circumference of one of the flanges. Turn the shafts over together to four different positions, 90 deg. apart. Measure dimensions *A* and *B* (Fig. 266), at point No. 1 for each of these different positions. Record the readings in a table similar to that shown in Fig. 266. If dimension *A* is the same for all the different positions of point No. 1, then the two shafts are parallel. If the different readings for *A* are not the same, then the shafts are not parallel. If they are not parallel, the parts of the unit must be shifted until these readings are the same for the four different positions. Similarly, if all of the readings for dimension *B* are the same, the axes of the two shafts are in line. But if these readings are not the same, then the axes are not in line. If they are not in line, the relative positions of the parts of the unit must be changed until they are in line. The alignment must be altered and rechecked until the various readings taken for dimensions *A* and *B* are, respectively, the same. A maximum variation of 0.004 in. might be allowed in either of these dimensions, but if it is possible to eliminate this variation, it should be done. In no case should the variation exceed 0.004 in.

447. NOTE.—AFTER A SATISFACTORY ALIGNMENT HAS BEEN OBTAINED, OPERATE THE UNIT FOR A PERIOD SUFFICIENTLY LONG TO INSURE CONSTANT TEMPERATURE CONDITIONS.—Prior to this operation, the coupling bolts must, of course, be inserted. Then shut the unit down, again remove the coupling bolts. Check to insure that the alignment is still satisfactory. If it has not changed, it may be considered permanent. Then the various parts of the unit should be securely and carefully doweled to the baseplate to prevent their shifting. If the alignment has changed during the trial run, additional adjustments and trials must be made prior to the doweling of the unit.

448. The Doweling Of The Parts Of The Unit To The Baseplate Is Exceedingly Important.—Correct alignment cannot be maintained unless the various parts are held in their respective locations by carefully installed dowels. After placing a unit in regular service, even though it was initially carefully aligned and doweled, the alignment should be checked at stated intervals.

449. An Example Illustrating The Aligning Of A 15,000 Kva. Synchronous Motor-Generator Set is given below.[1] This unit changes 50-cycle energy into 60-cycle energy at 15,000 volts. In Fig. 268 is shown the general arrangement

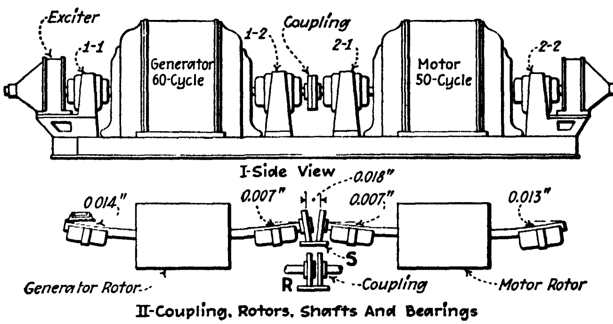


FIG. 268.—Diagram of the 15,000 kva. frequency-changer set, showing the shaft and coupling deflections exaggerated.

of the machine. There is a rigid coupling between the motor and the generator. An exciter is mounted at each end of the set. The operating speed is 600 r. p. m. The total weight is approximately 200 tons. The heaviest piece—the generator rotor—weighs 35 tons.

450. EXAMPLE.—The bedplate was carefully leveled and grouted in the usual manner, after which the other elements of the machines were assembled on it. In order to check the alignment roughly, a surveying instrument was first used to measure the height of each journal above a certain datum or specified elevation. After correcting for the diameters of the shafts, the center of each journal was found to be practically at the same level.

The shaft deflection at each bearing was measured by means of a sensitive machinist's level 18 in. long. Shims were inserted at the lower end of the level, between the journal and the level, until this initially lower

[1] *Power*, Aug. 21, 1923, p. 299.

end was raised to a level position. An exaggerated side view of the shaft deflection is shown at Fig. 268-*II*. The heavy weight of the rotating element in each case tended to deflect the shaft. The deflection at the generator outboard bearing 1-1 was found to be 0.014 in. with the exciter end high. The deflection at the generator coupling bearing 1-2 was 0 007 in. with the generator end of the journal low. This deflection is that for the entire 18-in. length of the level, which corresponds to a deflection of 0.0046 in. per foot. Deflections of motor bearings 2-1 and 2-2 were 0.007 and 0.013 in. respectively. After shimming the bearing pedestals to correct for this misalignment the shaft deflections were again measured, as will be described later. The deflections recorded above indicate only the general conditions of the rotating element and do not vitally concern the alignment itself.

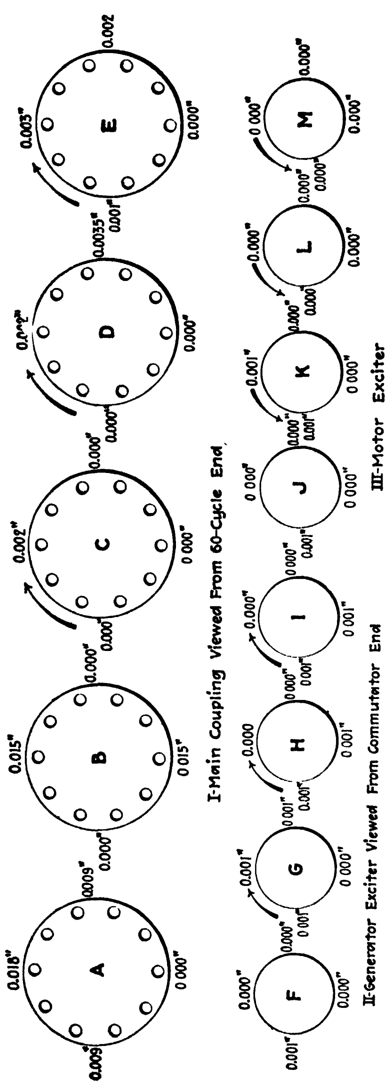


FIG. 269.—Measurements on the three couplings of the frequency changer indicate the absence of shaft "springs" or "unevenness."

The object of the aligning which is now to be explained, is to place the coupling flanges central with respect to each other and parallel in regard to their flat radial surfaces. The coupling bolts were removed and the two flanges were separated by 3/8 in. To check the centricity or central condition, a straightedge is placed across the coupling flanges at the top, the bottom, and each side. If the flanges are both parallel and central, the straightedge will bear evenly throughout its length, as at *R*, Fig.

268. If the flanges are displaced centrally, the straightedge, when contacting at the high flange, will not bear evenly on the low side of the flange —the one which is deflected toward the center. Since these flanges were out of parallel, it was possible to make only an approximate check, as at *S*. The flanges appeared to be central.

In order to test the parallelism of the two flanges, measurements were made between the two flanges, with thickness gages, at the top, bottom, and both sides. A solid piece was used to fill in most of the 3/8-in. gap between the flanges. Hence, only a comparatively few thickness gages were necessary. As is shown at *A* (Fig. 269) the flanges separated 0.018 in. at the top, 0.000 in. at the bottom, while at each side they opened 0.009 in. The flanges were therefore parallel with respect to each other horizontally, but were not parallel vertically. The fact that the opening at the top was 0.018 in. and the opening at each side was 0.009 indicated also that the flanges were machined true, since the sum of the horizontal measurements equals the sum of the vertical.

The next step in the alignment was to bring the flanges parallel with each other and then again to check the central condition. Hence, liners or shims amounting to 0.055 in. were added under the pedestal block, at bearings 1-1 and 2-2 (Fig. 268). This was to tip the exciter ends of both the shafts upward, so that the coupling flanges would be forced closer together at the top and thus become more nearly parallel. By carefully figuring the proper thickness of the required shims, the flanges in this instance were brought satisfactorily parallel by this one adjustment. Applying a straightedge at top, bottom, and both sides, showed the flanges to be satisfactorily central.

To check thoroughly the parallelism of the flanges, a series of measurements were then taken, as indicated at *B*, *C*, *D* and *E*, Fig. 269. The bearing pedestals were first inspected to insure that their holding bolts were turned tightly into place—so that there could be no shifting to disturb the shaft position. The measurements at *B* indicate that the flanges were (for all practical purposes) perfectly parallel. Instead of getting zero measurements at all four locations the top and the bottom measurements were 0.0015 greater than zero. However, both sets of measurements are practically equal. An error of 0.001 in., or possibly 0.002 in., is usually considered negligible when aligning machines of this character, although it is desirable to avoid any error whatsoever. A 0.0015 in. error is especially negligible when the vertical and the horizontal measurements check against each other and indicate accurate parallelism.

Several checks were then taken, as indicated at *C*, *D* and *E* (Fig. 269). Before taking each measurement, the motor rotor was given one-quarter turn (through a right angle), always in the same direction, while the generator shaft was held stationary. This operation is necessary to check for "springs" or other unevenness in the coupling flanges or the shafts. It might happen that the coupling flanges would show parallel due to both shafts being sprung in such a manner as still to keep the flanges

parallel when measuring at *B*, Fig. 269. In other words, if one shaft were sprung up and the other down, the flanges might still measure as being parallel from top to bottom. In order to check this, one of the coupling flanges is turned through 180 deg.—through one-half turn. Any spring that exists will then show its error by twice the amount of flange inclination. The readings at *C*, *D*, and *E*, show that the flanges were parallel within the allotted limits of error. The alignment was therefore considered satisfactory and there were no appreciable shaft springs.

The shaft deflections were then again measured at each bearing, with a level, as before described. In this case the bearing at 1-1 (Fig. 268) required 0.017 in. in order to bring the bubble to a level position; the bearings 1-2 and 2-1 both showed level at the journal. The bearing 2-2 required 0.0175 in. in order to show level. The top, bottom, and side measurements, with a straightedge, indicated that the coupling flanges were satisfactorily central.

In order to align the generator rotating element with its stationary element, the air gap of 5/8 in. was adjusted evenly. To do this, 0.114 in. thick liners were necessary under the generator feet. The air gap of the motor was adjusted at 3/4 in. evenly all around by adding liners of 0.125 in. under its feet.

The exciter on the 60-cycle generator was aligned correctly by adding liners of 0.08 in. between both outboard feet and the supporting pedestal, and liners of 0.071 in. between the inboard feet and the pedestal. The exciter of the 50-cycle motor required liners of 0.0855 in. at the outboard feet, and liners of 0.0795 in. on the inboard feet.

The 60-cycle-generator exciter couplings were loosened and the separation between their flanges checked as shown at *F*, *G*, *H* and *I* (Fig. 269). After each measurement the revolving element was given one-quarter turn. These measurements show the coupling to be very accurately parallel. The flanges were held central by the plug and recess centering fit. The measurements for the 60-cycle-motor exciter are indicated in *J*, *K*, *L* and *M*.

After the couplings were properly bolted, the machine was tested for insulation resistance. Then it was placed on the line and operated satisfactorily. In starting this set, oil is supplied temporarily under high pressure at each bearing. There are two oil grooves, one on each side of the bottom of the liners. This oil, under pressure, tends to lift the shaft from the journal. With the oil under pressure applied to the bearings, the entire rotor can be turned over by one man pulling on the 24-in. coupling. This ease of turning indicates a high degree of accuracy in alignment.

451. The Use Of Leveling Blocks And Shims, Instead Of Wedges, For Leveling The Bedplates Of Large Units, Particularly Turbines, is discussed in the following article, by Edgar

C. Barker, turbine erecting superintendent, General Electric Company.[1] He explains that it is sometimes difficult to avoid undesirable deflections when wedges are employed for leveling-large bedplates. The article describes an ingenious and practical method of providing a plane surface, composed of adjustable iron leveling blocks, for supporting the bedplate, and preventing undue strain in it while it is being installed. Furthermore these leveling blocks insure permanent alignment for future operation.

452. Cast-Iron Bases Of Turbines Or Other Machines Only Appear To Be Strong And Rigid.—When the machined surfaces, however, are placed accurately in parallel planes by means of careful leveling, the bedplate is found to be comparatively easy to bend or deflect, as indicated by a sensitive level. Permanent "sets" or deflections may be caused by strains in shipment, unloading, contraction from hot to cold, or the operations of wedging and leveling. It is sometimes necessary to remove these permanent deflections, when installing, by special distribution of wedges and pressure of weight or pull of foundation bolts. The bedplates of large or medium-sized machines remind one of the bending qualities of ordinary tin when checked for small deflections with a sensitive level.

453. It Is Troublesome When It Is Found Necessary To Move One Of The Bearing Pedestals Or Other Doweled Members In Order To Obtain Proper Side Alignment of a large steam turbine, the base of which has been leveled and set on sixty or seventy sets of good wedges and shims. It is not generally realized that the less localized strain that is placed on a base casting, the better the unit will operate and the longer the alignment will remain true and correct. The usual practice in leveling is to place the base at the proper elevation by means of wedges and shims and then correct the leveling accurately after the proper elevation has been reached.

454. Strains Are Often Produced By Driving The Wedges Unevenly; if wedges at diagonal corners are driven hard enough to lift the whole weight, an excessive deflection will occur in the middle. This would produce a twisting strain in the base which might be severe enough to cause a permanent deflection, which is the most difficult kind to remove and therefore should be avoided if possible. Such a permanent "set" or strain may be eliminated, as far as the leveling is concerned, by special distribution of wedges or bolt pressure. When anything occurs to eliminate the forces that tend to correct the strain, the deflection or twist will again assert itself.

455. The Forces Employed Forcibly To Straighten Out A Bedplate May Sink The Wedges Down Into The Foundation while

[1] From *Power* for Jan. 9, 1923.

grouting is in progress. An unsatisfactory alignment will then be produced after the grouting has set. Misalignment may occur, although correct alignment was produced originally, if slight vibration caused by the turbine or auxiliary parts, or by the plant in general, should allow the wedges that carry the excessive weight to work loose; in the case where wedges are withdrawn, an excessive local weight or force may loosen a portion of the grouting, which would eventually allow the machine to settle and become out of line. It is, therefore, most important to handle the bedplate carefully, so that no undue strains or permanent sets are introduced.

456. WHEN THE SECOND OPERATION OF CAREFUL LEVELING IS COMPLETED, IT MAY BE FOUND THAT THE SIDE ALIGNMENT OF THE BEARINGS OR OTHER ELEMENTS IS OUT, due to permanent sets, which may not be apparent from the leveling pads or other surfaces. The second operation of careful leveling is performed after that of bringing the machine to proper elevation. In order to effect proper side alignment without loss of time, it is sometimes forced by placing a jack against the member to be adjusted, so as to push it in proper alignment. The leveling will then appear to be seriously out in one or more places, which could not be passed as a satisfactory job of installing. It may become necessary to change the distribution of wedges or bolt pressure in order to bring correct side alignment and correct leveling at the same time, and still the item of proper elevation must be carefully adhered to. With these three conditions—elevation, leveling, and alignment to make satisfactory, it is a long journey to make ready for grouting.

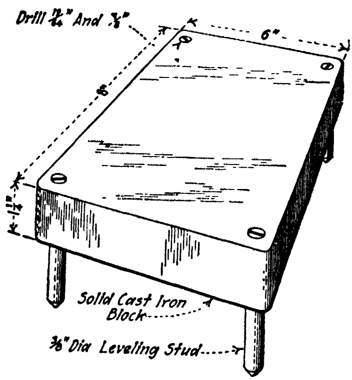


FIG. 270.—Details of leveling block.

457. NOTE.—THESE ALIGNMENT DIFFICULTIES MAY BE OVERCOME BY PROVIDING AN APPROXIMATELY LEVEL PLANE SURFACE COMPOSED OF IRON BLOCKS (Fig. 270) for the support of the bedplate. Undue strains are avoided when the bedplate is set on such supports or when an assembled turbine is placed thereon. Proper elevation can now be obtained by placing shims of the proper thickness between each block and the bedplate. It may be possible to pick up an entire unit of medium size with a crane if there are facilities for doing this, without introducing undesirable deflections in the bedplate; in such a case the proper shims, each one of an equal amount, can quickly be inserted. In other cases wedges may be used for lifting up the bedplate in order to insert the shims, and then withdrawn. It is evident that the amount of wedging can be readily gaged by the amount that the bedplate lifts off the iron blocks, and undesirable stresses can, therefore,

be easily avoided. Figure 271 illustrates the use of these iron blocks, which are cast-iron plates 6 × 8 × 1¼ in. supported by ⅜-in. bolts.

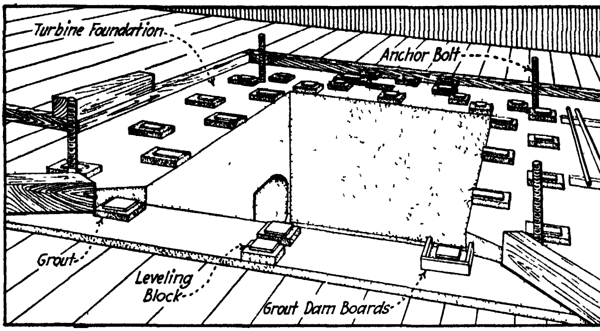


Fig. 271.—Leveling blocks grouted in place on foundation top, ready to receive the bedplate of a turbo-generator unit. The inner row of plates is to carry the inner edge of the turbine bedplate and the outer row is to carry the outer edge of the turbine bedplate.

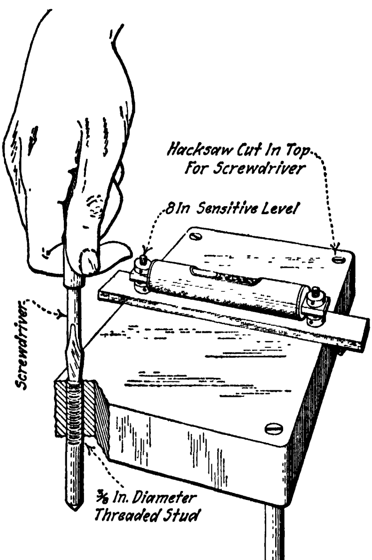


Fig. 272.—Each block is individually leveled by using a screw driver and a small level.

458. Note.—The Leveling Block May Be Quickly Leveled With A Screwdriver (Fig. 272) used on the supporting bolts. The entire plane surface can be produced by leveling each block with its neighbor by means of a straightedge and level (Fig. 273), or with the engineer's sensitive level and target, which are shown in Figs.

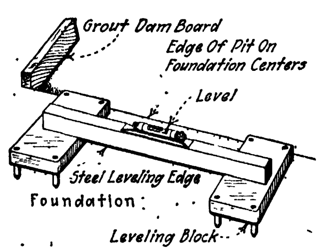


Fig. 273.—The tops of all of the leveling blocks are brought to the same elevation with a steel straight edge and a level.

235 and 214. With a sensitive level these can be brought up in an approximate plane surface very easily. If a carpenter's level is used, it

will be impossible to secure a satisfactory plane surface as such a level is not sufficiently accurate.

459. To Make A Leveling Block drill each corner of the cast-iron block with a 19⁄64-in. drill, and tap for 3⁄8-in. thread. Studs can be made by threading a long 3⁄8-in. rod from standard stock and then cutting it into proper lengths and slotting one end for the screwdriver with a hacksaw. The head of each screw should be below the upper surface of the block when it is mounted in position. The length of the studs should, therefore, be calculated beforehand, so that they will not be too long when the turbine is properly leveled.

460. NOTE.—LEVELING BLOCKS WHICH HAVE THREE SCREWS, INSTEAD OF FOUR, HAVE BEEN SUGGESTED by Walter C. Cary in *Power* for Mar. 20, 1923. Such blocks should be triangular in plan, instead of rectangular. These three-screw blocks would be desirable not only because of their lower cost but also because a plane surface can be much more readily and accurately determined by means of three points than by four.

461. NOTE.—AFTER THE BLOCKS HAVE BEEN SET, A DAM SHOULD BE BUILT AROUND EACH BLOCK AND GROUTING CAREFULLY POURED IN. After setting two or three days, the bedplate may be placed thereon. Fig. 271 shows these blocks leveled and grouted for the bedplate of a turbine unit. The blocks should be so located as to provide ample support for the heavy parts, such as the turbine cylinder and the generator. In addition to the advantages before mentioned for such plane surfaces, it will be seen that the turbine can be moved in a horizontal direction without disturbing its leveling appreciably. Furthermore if such a movement should take place at any time in the future, it would not effect the alignment as seriously as if the bedplate were supported on wedges. It is also comparatively easy to move a bedplate or a turbine-generator unit on an iron surface that corresponds to a plane, whereas any horizontal movement, when set on wedges, will immediately produce improper leveling and misalignment. This fact insures a great advantage when adjusting to the position which is required by the center lines of the station layout.

462. NOTE.—THE COST OF THE LEVELING BLOCKS IS VERY LOW, considering the satisfaction, speed, and reliability that they produce in the operation of installing. The time required, when the leveling blocks are used, for machine work, leveling, and grouting is often much less than that required in leveling and aligning the base of a large turbine with the use of wedges. Often the time in erection can be greatly reduced. The blocks may be made in a foundry if desired, or plates of rolled steel, 1 in. thick or thereabouts, may be substituted for cast iron if more convenient. When plenty of stock, and means of quick cutting are available, steel is often cheaper than cast iron.

463. NOTE.—IF NECESSARY IN AN EMERGENCY TO OPERATE A UNIT WITHOUT GROUTING, it is very probable that if such blocks are provided in advance operation for considerable periods can be maintained to better advantage than if the unit were mounted on wedges.

464. NOTE.—LEVELING BLOCKS SHOULD BE ARRANGED FLUSH WITH THE SIDES OF THE BEDPLATE or very nearly so, in which case they will not interfere with the finishing of the floor in the way that wedges often do, as the latter may extend considerably beyond the bedplate. Sometimes they are in such a location that they cannot be sawed off.

465. NOTE.—IT OFTEN HAPPENS THAT THERE IS A CERTAIN AMOUNT OF LOOSENESS BETWEEN THE FOUNDATION AND THE BEDPLATE, AND IF WEDGES ARE REMOVED TO TIGHTEN AT SUCH A POINT, THE ALIGNMENT IS SOMETIMES SERIOUSLY CHANGED.—It should be borne in mind that the grouting at first expands slightly and then, when it has permanently set, has undergone a certain amount of contraction, and usually is slightly smaller than the original space. The grouting, therefore, between the foundation and the bedplate should not be greater than 1½ in. thick at any point. Grouting carefully done, and as high as possible inside the base, will tend to hold the bedplate down toward the foundation.

466. TO PREPARE FOR GROUTING it is necessary to build a dam after the unit has been brought to the proper elevation and alignment with itself, as well as in respect to the center line required by the design of the station. The location of the steam and exhaust openings to the condenser and header, respectively, and also drain piping, air ducts, and conduits for the generators, etc., should be checked. A convenient method of building such a dam is to make a fairly stiff mixture of equal parts of fine sand and cement and plaster between the foundation of the bedplate with this material. After setting overnight, the main grouting can then be poured. Material for the dam is a rich mixture and therefore a first-class material for grouting, and consequently there is no objection to leaving this plastering in place.

467. NOTE.—IT IS JUST AS ESSENTIAL THAT A TURBINE SHOULD BE SECURELY SET AND GROUTED AS AN ENGINE for long life and perfect operation. The turbine builders of today, many of whom have been steam engine men, are aware of this fact. They make provision for grouting the base on the foundation more easily and with more openings, both inside of the base as well as outside, for pouring in the grout. It is not difficult to reach, with a stick 2 or 3 ft. long, any part of the base of a large-sized turbine, and if a dam as above described, has been built around the turbine and the base has been filled above the bottom to an elevation of 6 in. or even, as has been done in many cases, to 1 ft. the air under the bearing surface of the base will be expelled to such an extent that what remains will be of little consequence.

468. NOTE.—IT IS NOT NECESSARY TO PUDDLE THE GROUT TO PRODUCE A RELIABLE JOB.—I have removed turbines for shipment and change of location, which had been grouted by the method described

above, and also those that had been grouted by puddling the grout, and I know that the former were just as good. I have yet to see one case where the grouting failed. Where old engine practice had been followed and the unit had been grouted down with sulphur, the latter was as hard as when first put in where the air could strike it. But where the air was not in contact and the base could spring with vibration, the sulphur or brimstone could be blown away as a fine powder, showing that the turbine weight had been carried on the wedges that were placed under it for leveling.

QUESTIONS ON DIVISION 4

1. What operation follows the erection of a machine on its foundation?

2. What is the support of an electrical machine?

3. Define "Locating" a machine. "Fixing."

4. What are the two general types of levels used in the locating of machinery?

5. Which of the two above-mentioned types are most suitable for use in leveling large machines?

6. How did the spirit level derive its name?

7. How is the accuracy of a spirit level determined?

8. What is meant by the "radius of curvature" of the glass vial of a spirit level?

9. How is the curvature of a spirit level produced?

10. Why is the ordinary level purchased in the hardware or machinist's supply store not very accurate?

11. Describe the method of constructing an accurate spirit level?

12. How is the degree of sensitiveness of a spirit level expressed?

13. How is the degree of sensitiveness of a spirit level determined?

14. What degree of sensitiveness of a spirit level is most desirable for average use under ordinary conditions?

15. Where is the level placed when leveling the bedplate of a machine?

16. What is a hydrostatic level? Illustrate its use.

17. What type of levels are used in the erection of large machines as turbo-generator sets?

18. Why is the ordinary target used in surveying unsuitable for use in leveling machinery?

19. What type of target is suitable for use in erecting machinery?

20. Describe the construction of the General Electric Co., Micrometer Target.

21. Describe the use of the General Electric Co., Micrometer Target in leveling.

22. Why should a heavy plumb bob be used in the location of machines?

23. What should be considered in selecting the location for an electrical machine?

24. What comprises the "locating" of a rotational electrical machine which is shipped completely assembled?

25. What are the two general methods of locating rotational electrical machines which are shipped assembled?

26. When is the cut-and-try method of machine locating applicable?

27. When should the measurement method of machine locating be used?

28. In locating a motor which is belted to a shaft, what distance should be provided between the motor and the shaft?

29. What is the first step in locating a machine by the cut-and-try method?

30. Of what materials are "Raisers" made?

31. Describe the cut-and-try method of aligning an assembled belted machine to a shaft when both driven and driving pulleys have the same face width.

32. Tell how to align a belted machine to a pulley, using plumb bobs.

33. Describe a method of aligning a machine which has a pulley with irregular edges.

34. How can a T-Square be used for aligning small- and medium-capacity machines?

35. How can a T-Square be used to align two pulleys which have different face widths.

36. Describe the method of aligning a form for a concrete foundation.

37. What dimensions are necessary for the correct location of the anchor bolts in the measurement method?

38. What is the pulley overhang and how can it be obtained?

39. What should be used in aligning a motor on a concrete foundation?

40. What operation follows the alignment of a rotational machine which has been shipped assembled?

41. How are bedplates held accurately in position to prevent distortion?

42. How should a foundation be prepared prior to placing a bedplate thereon?

43. What are used in adjusting a machine to an accurate level?

44. Where should wedges be placed if anchor bolts are employed?

45. What is the best material to use in making wedges?

46. What should be checked after a machine, which has been shipped assembled, has been located, aligned, and leveled with wedges on its support?

47. What is the first step in grouting a bedplate to its foundation?

48. What composition is ordinarily used for grouting?

49. Describe in a general way the procedure in grouting a bedplate.

50. What are substituted for bedplates on some of the larger machines?

51. How are bearing pedestals adjusted in aligning them?

52. What should the line, used for the alignment of units which are shipped disassembled, consist of?

53. How is the sag in the tight wire, used for aligning a bedplate corrected?

54. Describe the method of using a tight wire in lining up a bedplate for a set shipped disassembled.

55. Describe the electrical method of calipering the distance between the inside of a bearing and a steel reference wire.

56. How is lateral adjustment of a frame on a bedplate made?

57. What is the most common cause of unsatisfactory machinery performance?

58. Why is it desirable to realign the parts of a machine after placing it on the purchaser's foundation?

59. How are two shafts aligned, so that their axes will come in the same straight line, when coupling flanges are employed?

60. How can the angularity of two shafts, having coupling flanges, be determined?

61. Why is doweling of the parts to the unit to the baseplate exceedingly important?

62. When is the use of leveling blocks and shims preferred to the use of wedges?

63. What results are produced when wedges are unevenly driven under a bedplate?

64. How is side alignment of bearings obtained?

65. Describe the method of leveling a machine with leveling blocks.

66. What precautions must be taken when removing the wedges from under a bedplate after the bedplate has been grouted?

DIVISION 5

ELECTRICAL-MACHINE MECHANICAL MAINTENANCE

469. Proper Maintenance Of Electrical Equipment saves money because it minimizes unexpected shut-downs and high repair costs. This proper-maintenance consists of careful periodical inspection to locate faults, which might ultimately cause breakdowns, and then, of repairing these faults. Therefore, the contents of this division will be devoted to methods of inspection and to methods of repairing such mechanical faults as may be found.

470. Electrical Equipment Should Be Periodically Inspected.—No definite rules can be given concerning the organization of an inspection department nor as to the frequency of inspection. The number of men required for the inspection will, of course, depend somewhat on the size of the installation and upon the kind of machinery which is used. See the examples given below. The frequency of inspection will vary with the class of apparatus, its use, importance, location, and certain of its constructional features. For example, a squirrel-cage, induction motor driving an ash conveyor would not require as frequent inspection as would relays protecting expensive equipment. The inspection and maintenance of electrical equipment should be under the supervision of the chief electrician, and the inspectors, however they may be organized, should report to him. The following examples are typical.

471. An Idea Of The Organization Required For A Plant may be obtained by comparison with the following two examples.

472. Example.—In one plant with 2,200 hp. in 1,500 motors ranging in size from ½ to 225 hp. and working 8 hr. a day, 6 days a week, the maintenance organization consisted of one foreman, three inspectors, one winder, and one helper. In a larger factory working 24 hr. a day, except Sunday, and having 500 power motors aggregating 9,000 hp., not including numerous smaller motors for portable tools, a large main-

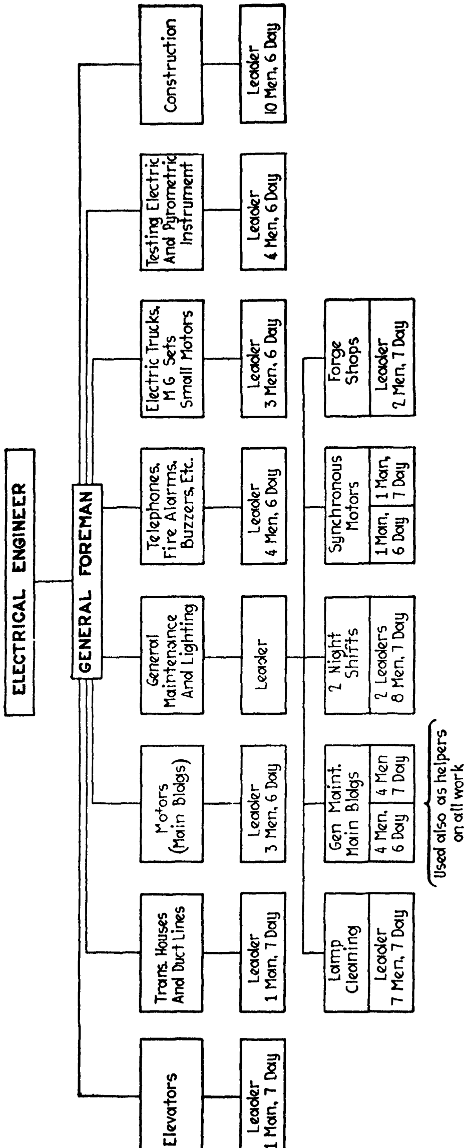


FIG. 274.—Personnel of a large inspection and maintenance organization for a plant working 24-hr per day and having 500 power motors aggregating 9,000 hp. (A. D. BLAKE, *American Machinist*, Jan. 5, 1922.)

MOTOR INSPECTION SHEET

PLANT

LOCATION #3 Bldg. Roof #2 LOCATION NO D.R-4 Middle Cab FACTORY NO MAKE Westinghouse STYLE NO. 160818

SERIAL NO. 1594183 TYPE C. S H P. 25 VOLTS 440 AMPS. 296 PHASE 3 CYCLES 60 R P M. 1160

STARTER Westinghouse Auto H. P. 20 - 30 AMPS. VOLTS 440 STYLE NO. 192523 FACTORY NO.

RELAY Westinghouse RANGE 40 AMPS TO 80 AMPS. #151643-A FACTORY NO. CUT-OUTS AMPS. VOLTS

CONTROLLER

MOTOR PULLEY Rockwood DIA. 11" FACE 10" BORE 2 3/8" MAIN LINE PULLEY Iron DIA. 19" FACE 9" MAIN LINE SHAFT LENGTH DIA.

MOTOR												STARTER			CONTROLLER		FULL	FRICTION	COMMENTS	
DATE	AIR GAP				OIL			ROTOR		NEATNESS		AUTO		OPEN	CONTACTS		LOAD	LOAD		INSPECTED BY
	TOP	BOTTOM	RIGHT	LEFT	FRONT END	PULLEY END	CHANGED	SLIP RINGS	BRUSHES	INSIDE	OUTSIDE	RELAY AMP	NEATNESS	FUSED AMP	DRUM	FINGERS	K W	K W		
												50								

FIG. 275.—Motor inspection form. This is printed on a 11 in. × 17 in. loose leaf sheet and fits in a loose-leaf binder. In the columns under the heading are spaces for checking inspections. (R. P. King of the East Springfield Works of the Westinghouse Electric & Mfg. Co., *Electrical World* for Feb 10, 1921.)

tenance organization (Fig. 274), consisting of many branches, was employed.

473. NOTE.—INSPECTION FOR THE MECHANICAL AND THE ELECTRICAL TROUBLES of the electrical equipment should be made at the same time. The inspectors should examine for mechanical defects, such as poor lubrication as well as for electrical defects. In this division only the mechanical maintenance and inspection problems are to be discussed. Electrical maintenance and repair problems, such as armature rewinding, are treated in other books by the author.

474. A Complete Record Of Inspections And Repairs Should Be Made.—Such records if properly kept will permit an analysis of the cause of troubles. By this means, the number of future troubles can be minimized. No definite form of record can be given here, because such a record will depend upon the size of the plant, the organization, and type of machinery. The records should not be so involved and complicated that their cost will be excessive.

475. NOTE.—SUCH RECORDS MAY BE CONVENIENTLY KEPT ON LOOSE-LEAF SHEETS OR ON CARDS, (Figs. 275, 276) and the cards arranged according to departments, or by some similar method, depending upon local conditions. A card record used in one plant contains the following data for each motor: (1) *Local-plant number of motor.* (2) *Department.* (3) *Horsepower load.* (4) *Make.* (5) *Type.* (6) *Manufacturers' serial number.* (7) *Speed.* (8) *Phases.* (9) *Voltage.* (10) *Shaft diameter.* (11) *Shaft length.* (12) *Size of fuses.* (13) *Repairs.* (14) *Date of repairs.* (15) *Apparent cause of trouble.*

476. The Conditions Of The Following Things Should Be Noted When Inspecting Motors: (1) *Bearing temperature.* (2) *Frame temperature.* (3) *Oil level.* (4) *Electrical Connections.* (5) *Cleanliness.* (6) *Vibration.* (7) *Air gap.*

477. Excessively High Bearing Temperature May Be Caused by: (1) *Broken or cracked bearing liner.* (2) *Insufficient oil.* (3) *Wrong kind of oil.* (4) *Bent shaft.* (5) *Belt too tight.* (6) *Armature not magnetically centered with respect to field.* (7) *Oil ring sticking.* If the bearing liner is worn out, cracked or broken, a new one must be installed (Sec. 516 to 606). The remedies for (2), (3), (4), and (5) are obvious. If the armature and fields are not magnetically centered, the fault can be corrected by driving the pole tips in a direction opposite to that of the armature. If an oil ring is stuck, the cause

INDUCTION MOTOR SHEET

No. of Motor 135 N

Location of Motor, Mill No. Bag Floor 2nd. No.

Rated H. P. of Motor 250 Frame No. 817688

Make of Motor G. E. Volts 2200 Cycles 60

Source of Supply #3 Feeder, #4 Sub-station

H. P. Required for Belts and Shafting 80

H. P. Developed 247 255 Avg.

Type I Poles 12 Form L

Speed Syn. 600 Full Load 588

Dia. Pulley 33 3/4" Face 30" Bore 6"

Length of Hub 17"

Keyway Length 17" Width 1 1/4" Depth 5/8"

Weight with Base 8000 Wt without Base

Cens. of holes Motor Feet, Width 24" Length 41"

Cens. of Holes Motor Base, Width 35" Length 41"

Dia. Base Bolts 1 3/8" Dia. Motor Bolts 1 5/16"

Height of Base 4 5/8"

Cen. of Motor to Bottom of Motor Foot 24"

Total Height from Base to Top of Motor 48 1/2"

Cen. of Motor to Cen. of Pulley 38"

Cen. of Motor to End of Tail Bearing 35 1/2"

REMARKS. Motor on floor, 6-240 Sp. Twister
5 Sew. Mch., 1 Press, 1 Bag Folding Mch.,
not running when test was made.

MACHINERY DRIVEN

1 Brush, 1 Press, 1 Bag Folding Mch.
3 Inspecting Fr. 5 Sew. Mch.
4-132 Sp. Twisters, 4-240 Sp. Spin Fr.
2-192 " " 16-228 " " "
6-240 " " 26-6 Sp. Winders
1 Balling Mch. May 19, 1921

FIG. 276.—A motor record sheet used by a large plant. A perpetual inventory of about 2,000 motors in service at the Amoskeag Manufacturing Company's plant in Manchester, N. H. is maintained by the electrical department in the form of $4\frac{1}{4} \times 7\frac{1}{4}$-in. loose-leaf sheets. A record of the troubles and their causes may be kept on the reverse side of the sheet.

of its sticking, such as a projection on the ring, should be ascertained and removed. Probably the cause for most of the bearing troubles is failure to provide sufficient oil. Therefore, by periodical and through inspection of all motors, the oil supply can be regularly replenished, thereby preventing a great deal of trouble which would otherwise occur.

478. Various Methods Are Employed In Lubricating Motor Bearings.—Figures 277 and 278 show the cross-sections of ring-oiled bearings. The method whereby a ring-oiled bearing is lubricated is shown in Fig. 279. This is the most popular method of lubricating sleeve bearings in motors used for general industrial purposes. Motors used on cranes, and for railway service are usually equipped with grease-packed bearings. Fractional horse-power motors and fans are usually equipped with wick-oiled bearings.

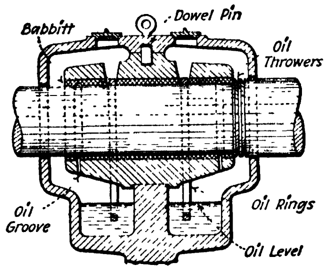


Fig. 277.—Cross section of a ring-lubricated bearing.

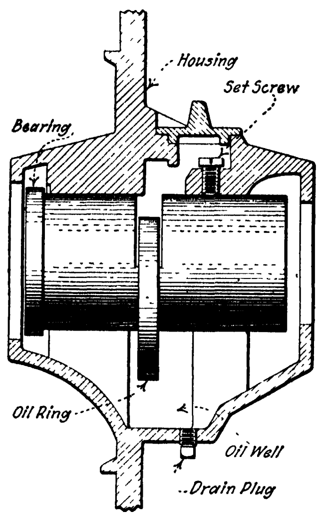


Fig. 278.—Cross section of a solid-type bearing in place.

479. Proper Bearing Lubrication Depends Upon The Maintenance Of An Oil Film Between The Shaft And Bearing Surfaces.—To insure a proper film of oil (Fig. 279) between the two surfaces, proper clearance must be allowed. The amount of clearance which is usually provided by one of the large machinery builders is given in Table 480. If the clearance is too small, the oil film cannot be maintained. Then the two metallic surfaces will contact and a hot bearing will result.

If the clearance is too great, the shaft will pound, making it impossible to maintain a suitable film of oil. This will not only produce a hot bearing, but the constant pounding will sooner or later ruin the bearing.

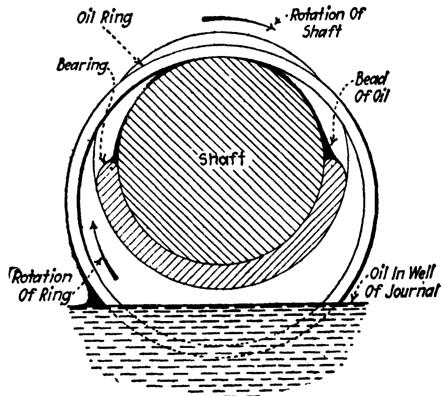


FIG. 279.—Diagram showing the method whereby a ring-oiled bearing is lubricated.

480. Table Showing The Limits For Clearance In Bearings Intended For High Speeds.

Diameter of shaft, in	Clearance, in.
½	0 0005 to 0.0010
1	0.0010 to 0.0020
2	0.0020 to 0.0030
3½	0.0030 to 0.0045
6	0.0045 to 0.0065

481. Oil Grooves Are Usually Cut In The Sides Of A Bearing To Aid In Spreading An Oil Film Over The Bearing Surface. (Fig. 280).—These grooves are cut at approximately right angles to the motion of the shaft. However, if a bearing surface is depleted excessively by oil grooves the bearing surface will be greatly decreased. Then the oil film, which is under a pressure sometimes as high as 200 lb. per square inch, cannot be maintained. In bearings of machines which have

no belt pull, such as motor-generators or motors which are direct-connected to centrifugal pumps, the oil grooves should be cut along the side of the bearings as shown in Fig. 280-*I*. For bearings which are liable to have a side- or up-pull, spiral grooves which have a pronounced slant, (Fig. 280-*II*), have been found to be the most effective.

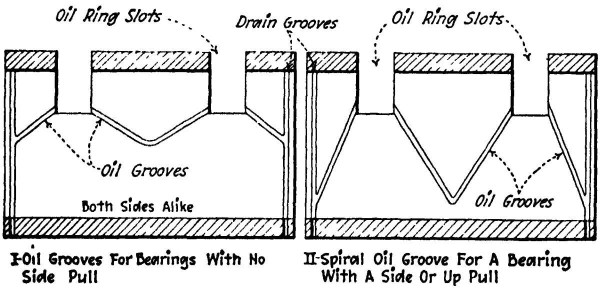


FIG. 280.—Sections of bearings showing the oil grooves cut in the sides to aid in lubrication.

482. The Effectiveness Of Bearing Lubrication Can Be Determined With An Electric Circuit.—The shaft and bearing pedestal of the machine are connected into an electrical circuit (Fig. 281), which consist of a bell, switch, and several dry

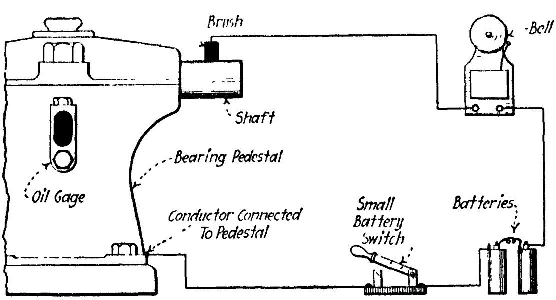


FIG. 281.—Diagram illustrating the method of determining the effectiveness of lubrication with an electric circuit.

cells all in series. Oil is a fairly good electrical insulator. A very thin oil film will break an electric circuit similar to the one shown. Now the purpose of oil is to minimize friction, by placing between the metallic surfaces a film of oil. Hence, if this film is complete and no metallic contact occurs, the

electrical circuit should remain open as long as the shaft is rotating. Therefore, if the switch is closed and the shaft is rotated, good lubrication will be indicated by the failure of the bell to ring.

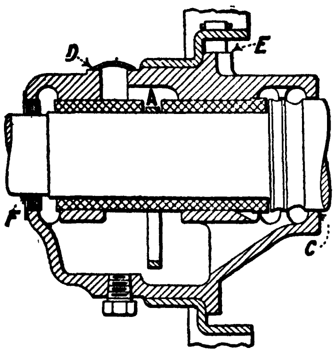
483. EXAMPLE.—It was desired to determine whether a heavy oil or light oil was best suited for a particular bearing. The heavy oil was poured into the bearing and the switch was closed. The bell began to ring vigorously, indicating that a metallic contact existed between the shaft and bearing. The shaft was then rotated at normal speed and under normal conditions of load. After a brief period the bell ceased to ring continuously. Finally it rang only spasmodically, at considerable intervals. This showed that the heavy oil formed its film slowly and also that it did not maintain it constantly, there being metal-to-metal contact at times.

The heavy oil was then completely cleared from the bearing and the light oil substituted. The switch was again closed and the shaft brought up to speed. Under these conditions the bell discontinued ringing after a few rotations of the shaft and remained silent until the shaft had again been stopped. This proved that the light oil was superior in this instance, that the oil film formed quickly, and that it was fluid enough to maintain a constant film between the shaft and the bearing surface.

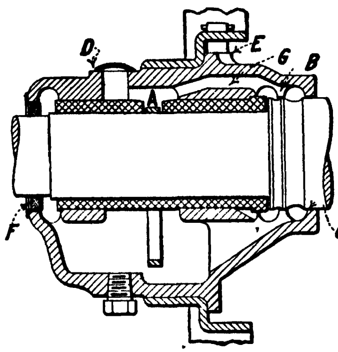
484. Oil Leakage From Bearing Housings May Result From Various Causes.—Improper care in filling the oil reservoirs is one of the frequent causes for a leaky housing. The evolution of the so-called *Leakproof Bearing Housing* is shown in Fig. 282.

485. Causes Of Oil Leakage In Bearing Housings Is Often Traced To The Lack Of Proper Care In Filling The Oil Reservoirs.—Figure 283 illustrates the cross-sections of a common type of bearing which is used in many small- and medium-sized motors. In general there are three vertical chambers, *O*, *P*, and *Q*, communicating with oil reservoir *R*. Oil leakage troubles are usually brought about through the existence of a region of low-pressure *A*, induced by the revolving member *B* acting as a blower. Therefore any oil finding its way into chamber *C* will be drawn out and distributed into the windings. It is therefore obvious that oil should be kept away from point *C*.

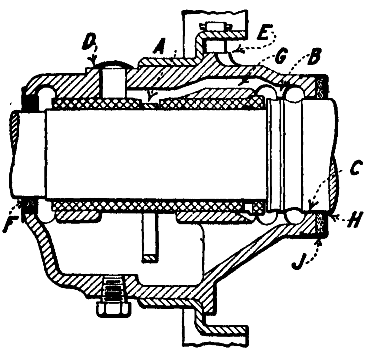
486. NOTE.—OIL MAY REACH POINT *C* FOR A NUMBER OF REASONS (FIG. 283-*I*).—Some of these reasons are as follows: (1) Annular groove



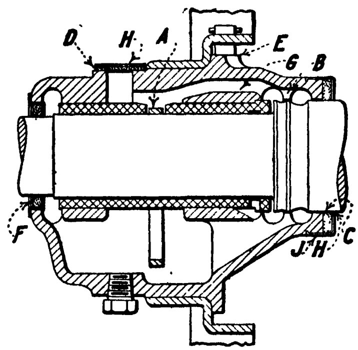
-This Design Has Become Obsolete Due To The Five Principal Difficulties Enumerated Below.



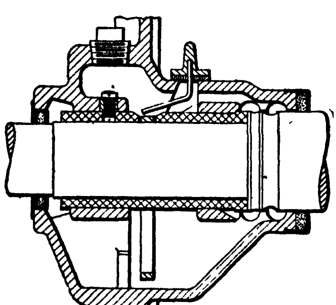
II-Old Design With First Improvement: Namely; The Addition Of A By-Pass For Air At G, To Overcome The First Cause Of Oil Leakage Indicated.



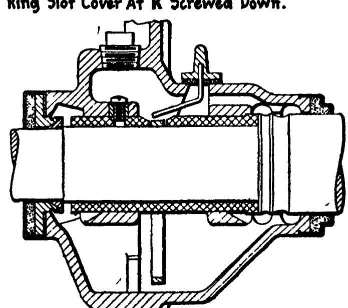
III-Old Design Improved By Addition Of An Inner-Bearing Cap (J) To Guard Against Oil Leakage From Careless Filling Of Oil Reservoir.



IV-Old Design With Maximum Possible Improvements Through Addition Of Tightly Closed Oil Ring Slot By Use Of Felt And Steel Oil Ring Slot Cover At K Screwed Down.



V-New Design Of Housing That Overcomes The Five Difficulties Underlined Under I.



VI-New Design With Addition Of Leakproof Devices To Prevent Leakage Characteristic Of Motors Running At High Speeds.

Fig. 282.

J (Fig. 283-*I*) may be too shallow or may be filled with dirt. Drain *K* may be partially or wholly obstructed with the result that groove *J* will become filled with oil which is then readily drawn out at *C*. This may be corrected by cleaning out groove *J* or drain *K*. It may be necessary to enlarge groove *J* or drain *K*. (2) The overflow at *H* (Fig. 283-*IV*), may be closed up or the hole drilled too high while the overflow plug *G* (Fig. 283-*III*) may be located too high or at an angle so that the oil level is raised until oil runs out at *C*. Retaping the hole for the overflow

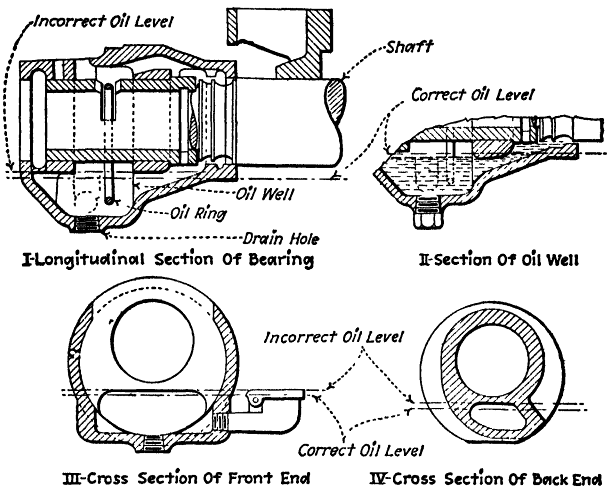


FIG. 283.—Cross sections of a bearing housing showing some of the causes of oil leakage. (S. C. HOEY, East Pittsburgh, Pa.)

plug *G*, forcing the tap downward so that the plug, when replaced, will give the correct oil level, will sometimes correct this trouble. Where this does not help, the old hole can be plugged with a pipe plug and a new hole

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FIG. 282.—Illustrations showing the evolution of leak-proof bearing housings. (*Industrial Engineer*, March, 1924.)

The five principle difficulties found in *I* are as follows: (1) No by-pass for air. Low pressure in chamber *B*, due to blower action, causes oil to escape at *C* if the oil level is temporarily raised too high. (2) Oil poured into the housing faster than it can escape from the overflow plug will overflow at *C*, in spite of absence of blower suction. (3) Oil slops out of oil ring slot at *D*, especially at high speeds. (4) Current of air entering at *D* and escaping at *C* carries oil vapor into the motor. (5) Oil leaks out past steady pin at *E*. (6) Portion of shaft at *F* alternately covered by oil-soaked felt and exposed to air (due to end play), throws off a fine oil spray which is carried by the draft of ventilating air into the motor.

The design shown in *IV* partially corrects the slopping out of oil and reduces current of air through the housing, indicated as troubles (3) and (4). However, it is very difficult if not impossible to secure a tight joint at *D* by using a cover such as *K* held on by radial screws.

drilled in the correct position on the opposite side of the housing. (3) The housing may be without a by-pass for air between the chambers *O* and *Q* (Fig. 283-*I*). In some housings, a by-pass is provided as at *D*. If this is obstructed, it should be cleaned out because a by-pass for air is a necessity.

487. Some Bearing Housings Have Grooves In The Top Half Of The Bearing Seat To Act As An Air By-Pass.—Due to imperfections in the casting these may not run clear through, or they may be so shallow as to be useless for their purpose. The flange of the bearing may almost entirely close them. These grooves must be of ample size and unobstructed. Some designs rely upon large clearance between the oil level and the bearing seat for the passage of air. In some cases the bearing seat may be cast much heavier than anticipated, taking the position *F* (Fig. 283-*I*). Atmospheric pressure in chamber *O* will then raise the oil level in chamber *Q*, due to the low pressure in *Q*, resulting from the escape of air through *C*. Chipping grooves on the bearing seat will usually remedy the trouble. Figure 283-*II* shows the effect on the oil level where an air passage between chambers *O* and *Q* is not provided.

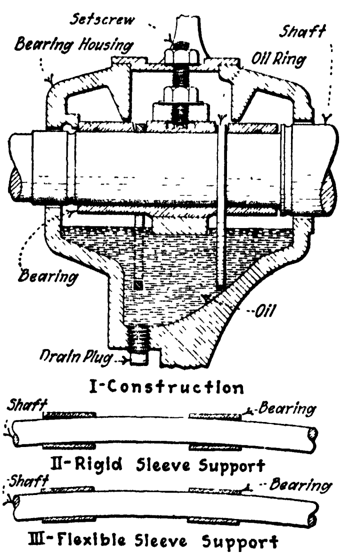

FIG. 284.—Diagram showing the construction of a motor bearing which permits a certain freedom of swing. In this type of bearing the sleeve and shaft are kept in alignment under varying load conditions, and in spite of shaft deflection. The effect of rigid support and flexible support of motor bearings are shown, exaggerated, in *II* and *III*.

488. NOTE.—A SELF-ALIGNING TYPE OF SLEEVE BEARING IS SHOWN IN FIG. 284.—Instead of a rigid mounting for the bearing sleeve, it is sustained by a semi-rigid support which permits a certain freedom of swing. This type of construction permits the bearing sleeve and shaft to remain in alignment under any condition of load and in spite of shaft deflection which is unavoidable.

489. Eddy Currents In Large Electrical Machines Have Caused Their Bearings To Heat.—The circulation of these currents through the bearings and shaft, which, having a poor electrical contact, causes heating and may also cause pitting of the shaft or bearings if continued for any length of time. Since these eddy currents constitute a loss, the best way to eliminate this loss is to insulate (Fig. 173) the pillow block and bedplate by inserting a fiber shim between them. This, of course, necessitates the lowering of the bearing to compensate for the thickness of the insulation.

490. An Example Of Bearing Pitting Due To Eddy Currents And The Method Of Its Correction is described in the following by J. W. Sloane from *Power* for Nov. 11, 1924.

The trouble was in the bearings of a 5,000-kw. turbo-generator unit. It was not discovered until considerable pitting of the generator bearings

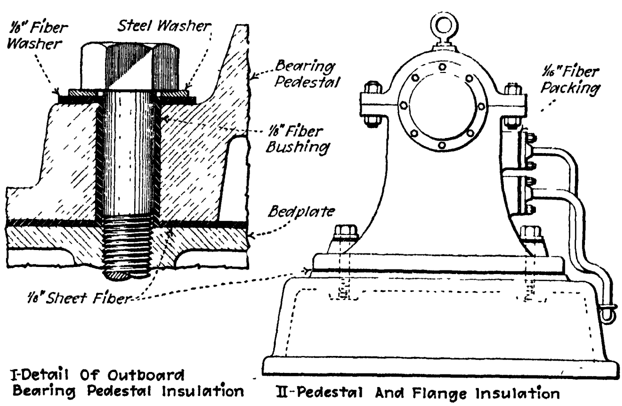

FIG. 285.—Methods of insulating the bearings of a turbo-generator unit to prevent eddy currents from pitting them.

had occurred. Our first indication that induced current was flowing through the shaft and journal was when a flash was noticed, by the operator, to jump from the vertical shaft, which drives the oil pump, to the surface of the oil in the base of the turbine.

To correct the trouble permanently the outboard bearing pedestal was insulated as shown in Fig. 285. A piece of sheet fiber was inserted between the pedestal and the bedplate. The holding-down bolts were insulated with fiber bushings and washers, as shown in the detail. The same method was used on the oil-pipe flanges and bolts. The ordinary packing on the pipe flanges was replaced with a fiber gasket which was

well coated on each side with shellac just previous to putting it into place. This method of insulating stopped the flow of current and consequently the pitting action.

491. Bearing Trouble Can Frequently Be Caused By Oil Rings Sticking.—Oil becoming foul and gummy is the most frequent cause of sticking oil rings. In dirty and gritty places it is almost impossible to keep the ordinary motor bearings clean. However, in motors of modern design the bearings have been so developed that they are practically dust tight. Occasionally, a bearing may be supplied with an oil which is too heavy, which will prevent the oil rings from functioning properly. Where this occurs a lighter oil will usually remedy the trouble.

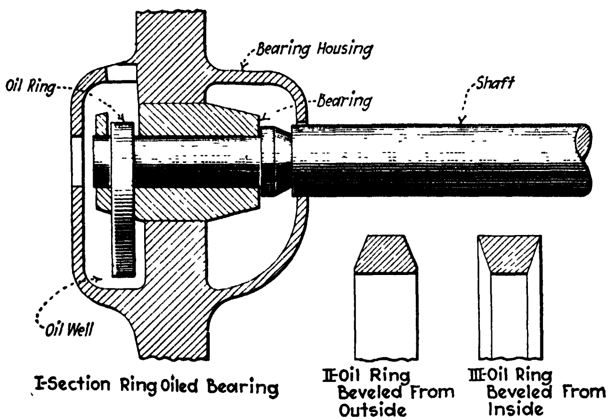

FIG. 286.—Illustrating a sectional view of a ring oiled bearing, and several types of oil rings. Oil rings which have bevelled sides are always preferable because they do not tend to stick to the sides of the oil-ring slots.

492. NOTE.—OIL-RING TROUBLES CAN OFTEN BE REMEDIED BY BEVELING, SLIGHTLY, THE SIDES OF THE RINGS (Fig. 286).—If the side faces of the rings are flat they tend to adhere—and sometimes do adhere—to the flat sides of the oil-ring slots. By beveling the ring sides, this adhesion is prevented.

493. EXAMPLE.—In one motor, which originally had rings with flat sides, the oil rings would normally "creep" at a very slow speed—possibly 2 or 3 r.p.m.—whereas they should rotate at 30 to 40 r.p.m. Under certain conditions the rings would start to rotate with the shaft and attain normal speed. But soon each ring would shift toward one side of the slot and there slow down, hugging closer and closer to the slot

side until there was only a very thin oil film between the ring side and the slot side. Then the ring would almost cease to rotate. This difficulty was corrected by beveling the sides of the rings.

494. Note.—Faulty Bearing Lubrication Can Occasionally Be Caused By The Oil Ring Having Come Out Of The Oil-Ring Slot.—When this happens the oil ring no longer functions properly and oil is not fed to the bearing. The oil ring may have been damaged or bent out of shape due to careless assembly of the bearings. This frequently causes the oil ring to stick in the slot thus preventing it from functioning properly. Since the oil rings are usually visible, an inspection will ordinarily reveal any of these troubles.

495. Excessive Frame Temperature Is Usually Caused By Excessive Current Flowing Through The Motor Windings, which may be produced by overload or faults in the windings. Another cause for heating is poor ventilation of the motor windings, which has clogged the ventilation ducts. Occasionally a motor which was designed to develop, when open, a given horsepower, is enclosed with a metal or wood cover, to prevent dust and dirt from accumulating in the machine. Such a cover prevents the proper ventilation of the motor. The result is excessive temperature.

496. Note.—The Hand As A Means Of Determining The Temperature Of A Machine Leads To Inaccurate Conclusions.—Frequently the temperature of a motor frame may be thought to be excessive, when felt with the hand, yet by properly measuring its temperature with a thermometer it may be found to be below the rated temperature rise. To measure the temperature of a motor with a thermometer, hold the bulb of the thermometer against the frame of the machine with a wad of putty. The temperature thus obtained will be the approximate temperature of the machine. Now, the temperature rise of the motor is usually stamped on its nameplate. Most machines are designed for a 40-deg. temperature rise. That is the temperature of the motor at full load will be 40°C. above the temperature of the surrounding air. Thus if the temperature of the surrounding air is 20°C. the temperature of the motor at full load would be: $20 + 40°C. = 60°C.$ Some machines are designed for a 55°C. rise. This would result in a temperature of 75°C. for the motor with the surrounding air at 20°C. The motor frame at this temperature would feel very uncomfortable to the hand.

497. Inaccurate Alignment Of Geared Machines May Cause Frame Heating.—Where geared motors are not solidly bolted and clamped down, sudden loads may cause the gear wheel to be forced away from the pinion. This may result in deflec-

tion of the shaft and the springing of the armature against one side of the field. It may cause the binding wire to rub on the pole pieces and produce local heating and breaking of the binding wire. The pinion should be accurately lined up and the foundation and bolting of the motor secure, without any "give" at the pinion. Sometimes a new set of foundation bolts may be necessary, or perhaps some reinforcement of the foundation. The armature should run true, that the air gap may be equal on all sides, with as small a bearing clearance as possible The pinion should be tested to insure that its bearing is held rigidly in place.

498. Electric-Machine Bearings Are Usually Equipped With Oil-Level Indicators.—One form of oil gage is shown in Fig. 281. Another form of oil-level indicator consists of a hole in the side of the journal. When the oil is at the correct level it is even with the top of the hole. With either of these two types of oil-level indicators the maintenance man can determine at a glance the level of the oil in the bearing.

499. Poor Electrical Connections Nearly Always Manifest Themselves By Excessive Heating At The Connections.—Poor electrical connections are usually caused by loose or dirty connections. When such connections exist in the windings of electrical machinery they are manifested in various ways depending upon the type of machine and the part of the machine in which the poor connection exists.

500. NOTE.—POOR ELECTRICAL CONNECTIONS IN THE ARMATURE WINDINGS OF A DIRECT-CURRENT MACHINE USUALLY CAUSE SPARKING OF THE BRUSHES.—Excessive heating of the armature winding and low speed also frequently accompany poor armature connections. Poor connections in the shunt-field circuit of a direct-current generator usually cause failure of the generator to build up its voltage. In a direct-current motor, excessive speed frequently occurs from poor field connections.

501. Early Designs Of Squirrel-Cage Induction Motors Experienced Much Trouble Due To Poor Connections Of Their Rotor Bars.—These poor rotor-bar connections usually caused the motor to fail to start under load, and frequently prevented the motor from attaining its rated speed. A poor connection in the armature winding of such a machine is usually, accom-

panied by excessive heating of the remaining portion of the winding which does not contain the faulty connection.

502. Cleanliness Of Electrical Apparatus Is One Of The Requisites For Satisfactory Operation.—Since it is almost impossible to prevent the accumulation of dust and dirt in the windings and other parts of some electrical apparatus, especially apparatus which is of the open type and operates in dusty locations, it is imperative that periodic inspections and cleanings be made. The frequency of these inspections will be largely determined by the conditions under which the apparatus operates. Some apparatus will require daily inspections while

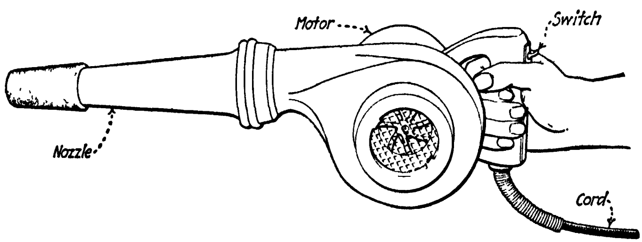

FIG. 287.—Illustrating a convenient form of portable blower which serves admirably in cleaning electric motors and apparatus. (Manufactured by the CLEMENTS MFG. CO., Chicago.)

inspections every two weeks would suffice for others. Figure 287 shows a convenient form of blower which is very effective for cleaning electrical apparatus.

503. NOTE.—ALTHOUGH COMPRESSED AIR HAS BEEN USED EXTENSIVELY FOR CLEANING OUT MOTORS AND GENERATORS, IT HAS ITS DISADVANTAGES.—The pressure of the air is usually much in excess of the value required. This has the effect of tending to injure the windings or insulation of the machine. The moisture which also usually accompanies compressed air is injurious to electrical windings.

504. The Air Gap Between The Armature And Field Varies With Different Sizes, And Types Of Machines.—Alternating-current induction motors have a much smaller air gap than direct current motors of the same capacity. The air gap or clearance, as it is sometimes called, varies, from 0.0125 in. to 0.5000 in. for alternating-current motors. From the above it is obvious that the wear of the bearings of such machines should be carefully observed. Several manufac-

turers have adopted ball bearings for these machines. By the use of these bearings the wear is minimized and thus smaller air-gap clearance is possible.

505. A Clearance Gage Is Usually Furnished With Alternating-Current Motors.—The gage (Fig. 288) usually consists of

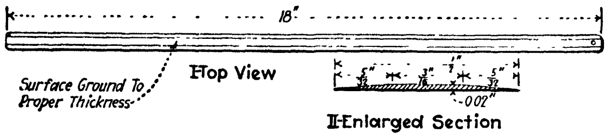

FIG. 288.—Diagram illustrating an air gap gage. This gage is for a 25 hp. motor.

a steel strip about ½ in. wide and 18 in. long. It is ground to a thickness of a few thousandths of an inch less than the air-gap length. When it is possible to slip the gage between the rotor and stator (Fig. 289) of a machine at any point throughout its periphery, then the clearance is within safe limits. When it is impossible to slip the gage between the rotor and the stator, it is an indication that the bearings have become worn or the rotor and stator are not in proper alignment. The necessary steps should then be taken to restore the air-gap clearance to a safe value, otherwise if the rotor should rub the stator, damage to the windings usually follows and a burn-out results.

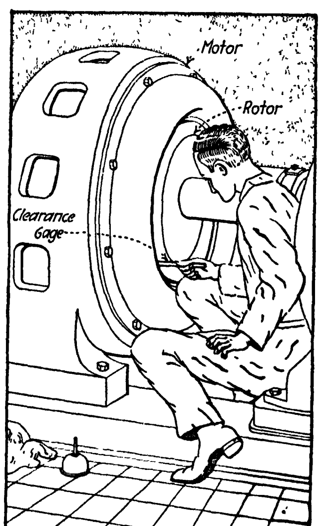

FIG. 289.—Gaging the air gap of an alternating current motor. (*Electrical World*, Nov. 6, 1920.)

506. NOTE.—WHEN GAGING THE AIR GAP OF A BELTED MACHINE THE BELT TENSION SHOULD BE AS UNDER NORMAL OPERATION.—If the belt pull is in an upward direction, the wear on the bearings will be on their upper surface. Now if the tension of the belt is removed and the motor is not operating, the rotor shaft will rest on the lower surface of the bearing. Thus under the above conditions

the wear on the bearings may have reached a dangerous point and yet an examination of the air-gap clearance will indicate a safe value.

507. An Uneven Air Gap Around The Rotor Of An Electrical Machine Frequently Causes Uneven Currents To Flow In The Armature.—This effect is most noticeable in direct-current motors and generators which are not equipped with equalizer connections. It manifests itself by causing sparking at the brushes and heating of the winding.

508. Vibration Of Electrical Machinery May Be Caused By Mechanical Or Electrical Unbalance.—Most cases of unbalance are due to the mechanical unbalance of rotors. A rotor which has been rewound and placed back into service without being balanced may vibrate. This may be caused by an uneven distribution of the winding on the ends of the armature core, which produces a static unbalance. Loose parts on the rotating members of a machine cause an unbalance. An uneven air gap frequently produces unbalancing due to the uneven magnetic force exerted on the armature at different positions. An electrical unbalance is caused by an uneven distribution of the current flow through either the stator or the rotor windings. Faulty or damaged coils (in an armature winding) which have been disconnected from the armature circuit constitute one cause for an uneven current flow through the armature.

509. Various Methods Are Employed To Balance The Rotors Of Electrical Machines.—Figure 290 illustrates a common method employed by some shops to determine whether or not an armature or rotor is balanced. The apparatus consists of two parallel ways upon which the armature, which is to be balanced is placed. The ways are first leveled by turning the adjusting screws. The armature is given a slight roll and its behavior upon coming to rest determines whether or not a balanced condition exists. If the armature comes to rest in any position whatsoever, it is considered to be balanced. If the armature always comes to rest in the same position after several trials, it is mechanically unbalanced. This mechanical unbalanced condition is usually rectified by counterbalancing the *heavy* side of the armature. This is frequently done by adding weight to the *light* side in

the form of solder applied to the bands which retain the coils to the core. Figure 291 illustrates a convenient form of balancing tool.

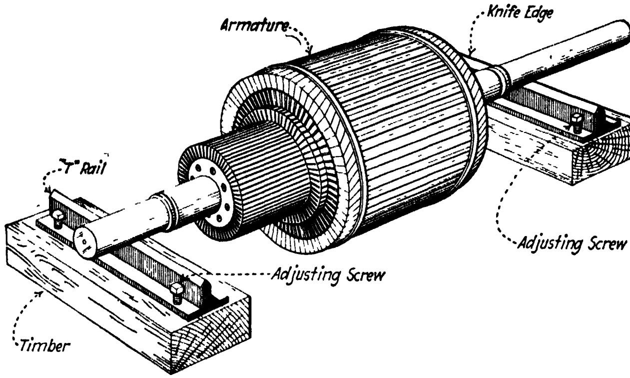

Fig. 290.—Method of determining whether or not an armature is balanced.

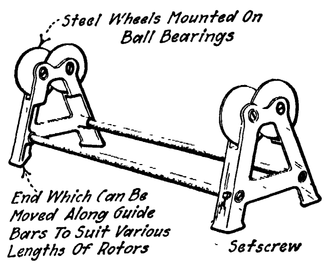

Fig. 291.—An accurate balancing tool.

510. Several Balancing Machines Are Manufactured With Which Accurate Results Can Be Obtained.—Figure 292 illustrates a combination static and dynamic balancing machine manufactured by the *Vibration Specialty Co., Phila., Pa.* It can be instantly set for either static or dynamic balancing and very accurate results of great accuracy can be obtained. This machine is not suitable for large, heavy rotors. For large rotors special equipment is designed.

511. The Mechanical Troubles Which Occur Most Frequently In Rotating Electrical Machinery Are Bearing Troubles.—Bearing replacements should, when feasible, be

made from bearings furnished by the manufacturer of the machine. The two principal reasons for this are: (1) *It is ordinarily cheaper in first cost.* (2) *A bearing made by the manufacturer will usually give better service than one which is*

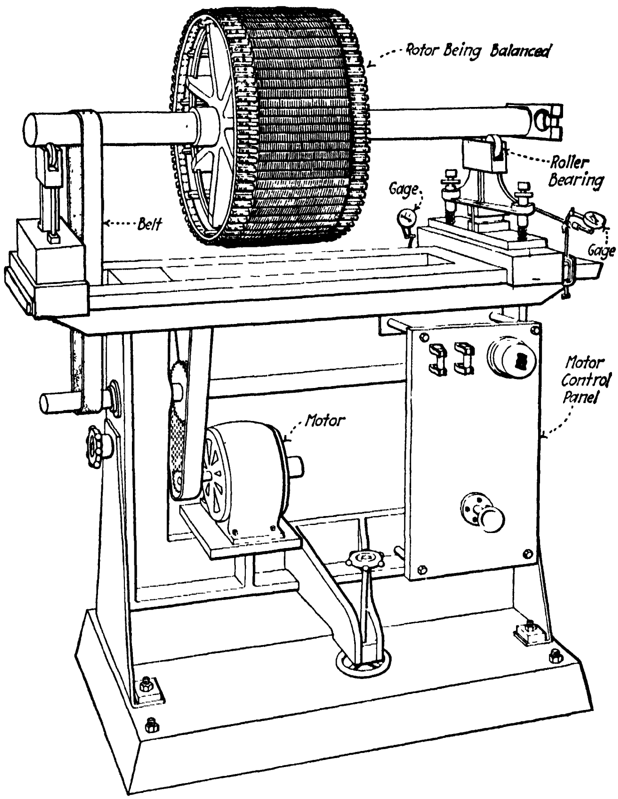

FIG. 292.—A combination static and dynamic balancing machine. (Manufactured by the VIBRATION SPECIALTY Co., Philadelphia, Pa.)

poured in the shop. For these reasons, where large numbers of similar motors are contained in an installation, a number of bearings which are made by the manufacturer should be kept in stock. However, for motors of old types and in emergencies, it is absolutely necessary that a new bearing be made in the shop. For this reason the following sections will

treat of methods of removing pulleys and pinions (to permit the removal of solid sleeve bearings) and of making and installing new bearings.

512. Bearing Trouble Is Sometimes Caused By The Shouldering Of The Rotor Of The Machine.—By "shouldering" is meant the shifting of the rotor to one side until the magnetic fields of the rotor and the stator coincide. Occasionally there is not sufficient end motion of the rotor to permit the two magnetic fields to coincide. The result is a pressure against the end of the bearing. The pressure against the end of the bearing causes the bearing to heat. This trouble can frequently be remedied by moving the core on the shaft in a direction opposite to that of the shifting of the armature. When this is not practical, the adjustment of the bearings may effect a remedy.

513. High-Speed Centrifugal Pump Motors Frequently Experience Hot Bearings.—Such motors are usually direct-connected to the pumps and it is difficult to ascertain whether the hot bearing is caused by the shouldering of the motor or by the end thrust of the pump rotor. By removing the coupling and operating the motor, it can be easily seen whether the thrust is caused by the shouldering of the motor. If there is no shouldering, the coupling should again be put on and the coupling bolts put in, leaving a space between the two halves of the coupling so that the pump rotor can move lengthwise in its bearings. The motor can then be started, and if the pump rotor shifts over toward the motor it is then evident that the heating of the bearing is due to the end thrust of the pump rotor. If the heating is thus caused by the end thrust of the pump rotor, a new bearing which has a thrust bearing end should be placed either on the pump rotor shaft or the motor shaft in place of one of the regular bearings.

514. NOTE.—BEARING TROUBLES ON DIRECT-CONNECTED UNITS WILL RESULT FROM IMPROPER ALIGNMENT OF THE UNITS.—Machines which are not level on their foundations frequently develop bearing troubles. The remedies for these bearing troubles are usually self-evident. The procedure for correcting such troubles is outlined in Div. 4.

515. The Procedure In Repairing Electrical Machine Bearings is about as follows: (1) *Remove pulley or pinion, if*

any. (2) *Remove bearing from housing.* (3) *Make a new bearing or repair the existing one if possible.* (4) *Replace the bearing in the machine.* These processes will be treated in succeeding sections.

516. Note.—Electrical Machine Bearings Are Of Two Types: (1) *Sleeve bearings* (Fig. 293-*I*). (2) *Split bearings* (Fig. 293-*II*). Sleeve bearings are used for practically all machines of capacities up to about 5 hp. For machines of 5 to 50 hp. either sleeve or split bearings may be mployed. Sleeve bearings may again be divided into two classes: (*a*) *Solid sleeve bearings.* (2) *Lined sleeve bearings.*

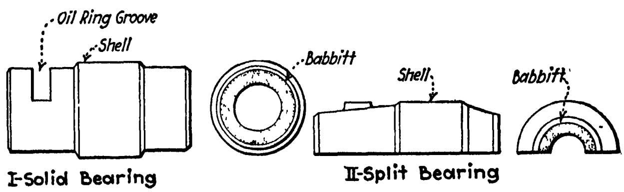

FIG. 293.—A solid and a split bearing.

517. Occasionally A Sleeve Bearing Which Has Run Hot And Seized The Shaft, Can Be Removed, Scraped, And Put Back Into Satisfactory Service.—The problem that often arises is how to remove the bearing from its housing. This can usually be acomplished by loosening the set screws which retain the bearing, lifting the oil ring out of the oil-ring slot, and then working the end plate or housing off of the bearing. A suitable puller (see following sections) should then be made to pull the bearing from the shaft.

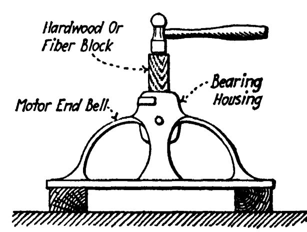

FIG. 294.—Diagram showing method of driving out bearing shell from a housing in a motor end bell.

518. The Removal Of A Sleeve-Bearing Shell May Be A Problem.—Whatever method may be employed, care must be exercised not to damage the shell, or the oil ring, (if the bearing is of the ring-oiled type). Before attempting to remove the shell, a careful inspection of the bearing housing should be made to insure the removal or loosening of all screws which retain the bearing shell. The most common method of remov-

ing a bearing shell is by driving it out with a block of hardwood or fiber, (Fig 294). When the bearing shell is shouldered, the proper direction in driving must be observed. Before driving out the bearing shell of a ring-oiled bearing, the oil ring must be lifted out of the slot to prevent damage to the oil ring and shell.

519. Note.—A Press, If Available, Is An Effective And Economical Tool For Removing Sleeve Bearings.—Figure 295 illustrates a type of arbor press which is suitable for pressing bearing shells from bearing housings. A pressure of over 6 tons can be exerted with a force of 100 pounds applied upon the lever.

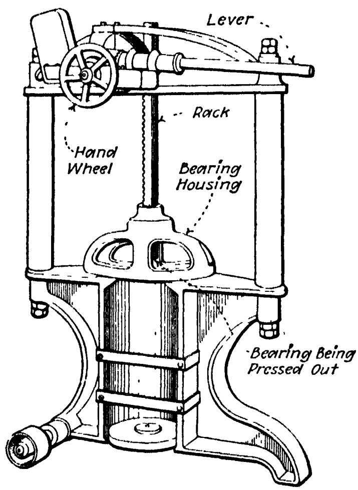

Fig. 295.—An arbor press which is very effective for removing sleeve bearings from their housings.

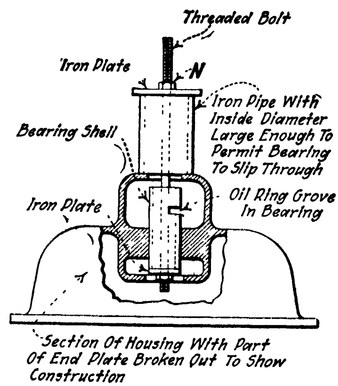

Fig. 296.—An effective method of removing a bearing shell from a motor end-shield. By tightening nut "*N*," the bearing shell is pulled out of the housing without injury.

520. When The "Driving-Out" Method Of Removing A Bearing Shell Fails, Other Methods Must Be Devised.—Figure 296 illustrates an effective method of removing a bearing shell. The required parts can usually be found around the ordinary shop. A threaded rod is passed through the bearing and bolted to an iron plate at the bottom of the bearing. This plate should be a little smaller in diameter than the outside of the bearing, to permit it to pass through the part of the

housing into which the bearing is pressed. An iron pipe is then slipped over the threaded rod and a second iron plate is slipped on the rod. The inside diameter of the iron pipe should be large enough to permit the bearing to slip through it. A nut N is then screwed onto the rod and gradually tightened until the bearing is forced out. The rod should be so threaded that the nut can be drawn up sufficiently to pull the bearing entirely out of the housing. Other effective bearing and pinion pullers are illustrated in Figs. 297, 298, and 299.

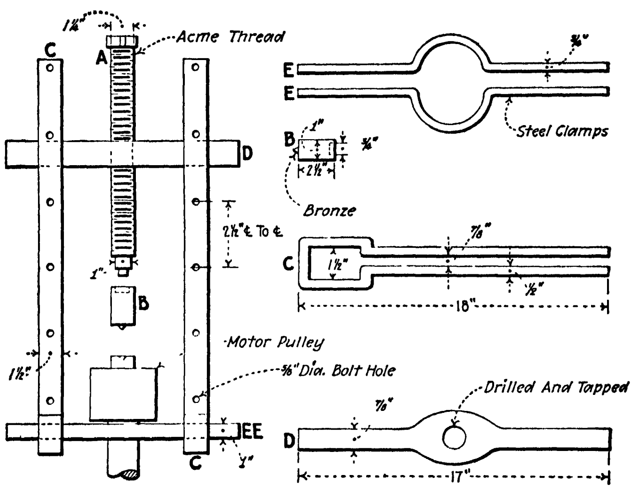

FIG. 297.—Construction details of a home-made pinion and pulley remover. (*Electrical World*, Vol. 77, No. 1, Page 50.)

521. NOTE.—A "HOOK"-BEARING PULLER FOR THE REMOVAL OF SLEEVE BEARINGS is shown in Fig. 299. The device consists of three or four hooks made of square iron or steel bent at both ends as shown at *III*. These are slipped into the sleeve which is to be removed. They are held against the inside of the sleeve with a piece of pipe. A threaded rod is then passed through the sleeve and a large washer put against the pipe. The other end of the rod passes through a piece of flat iron which is bent in a U-shape and rests on the inner side of the bearing housing. By tightening on the nut N, the sleeve is forced out of the housing.

522. NOTE.—THE CONSTRUCTION OF ANOTHER TYPE OF BEARING PULLER is illustrated in Fig. 300. The various dimensions will have to be changed to meet the different jobs to which the puller is to be adapted. In the case illustrated the space between the bearing and rotor was limited

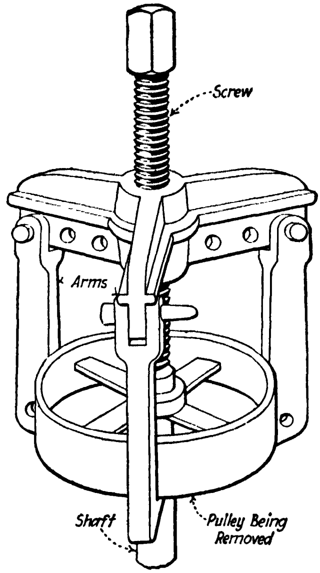

FIG. 298.—A three arm pulley or pinion puller. (HAMMACHER SCHLEMMER Co., Puller No. 3.)

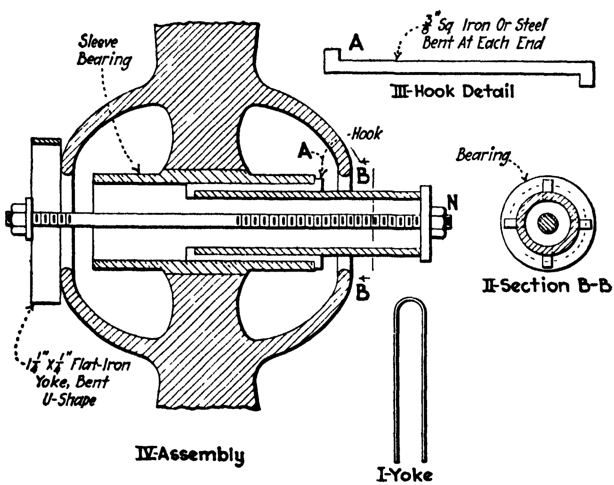

FIG. 299.—Method of removing a sleeve bearing from a bearing housing. (*Industrial Engineer*, Sept., 1924.)

to ½ in., which did not leave much room in which to work. By tightening the nuts on the stud bolts, the bearing is pulled off of the shaft by the pressure exerted on the end of the shaft through the bar, *B*. When the bearing is removed the shaft and bearing should both be cleaned and scraped, and can then be put back into service.

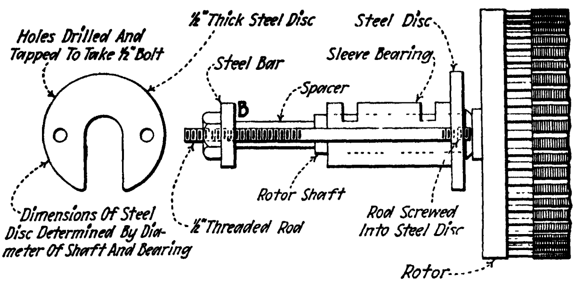

FIG. 300.—Diagram illustrating the construction of a puller used for removing a bearing which has siezed the shaft.

523. A Home-Made Puller For Drawing Off Motor Pinions And Pulleys Can Be Easily Constructed.—Figure 297 shows a type which is effective. To remove a pinion, gear, or pulley from a motor shaft, the clamps *EE* are placed above and below the shaft, against one side of the pinion. Pieces *CC* are then slipped over the ends of the clamps *EE* and the threaded cross bar *D* is assembled into place. The cross bar *D* is threaded to take screw *A*. Centering plug *B* is placed on the end of the shaft and is followed up by the plugged end of the screw *A*. By turning on the screw *A* with a wrench, the shaft is pushed out of the pinion.

524. Bearing Linings Are Generally Made Of Soft Metal To Minimize Wear On The Shaft.—Where they are thus made of soft metal, practically all of the wear is confined to the bearings —rather than to the shaft. The bearings can be readily replaced, but the shaft can not. An idea of the importance of this feature can be obtained by considering the shaft of a rotor. Often a great deal of work is involved in replacing such a shaft, particularly if the commutator is keyed directly upon it, instead of upon a spider attached to the armature core laminations. Where the commutator is keyed directly to the shaft, to remove the shaft, all of the commutator connections must be unsoldered and the commutator removed from the shaft and

the wound core; after which the core, with the windings, is removed. If the commutator is shrunk or keyed to the armature spider, the commutator, armature core, spider, and all are removed in one piece. In either case it is evident that it is cheaper and easier to renew the bearings than the shaft.

525. There Are Two General Methods Of Making Babbitt Bearing Linings.—One method (Fig. 301) consists in pouring the bearing so that the bore will be somewhat smaller than the

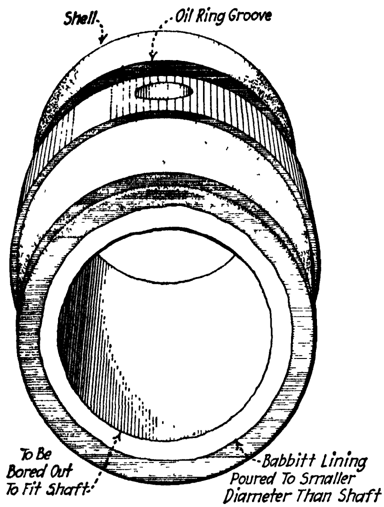

FIG. 301.—Bearing shell with babbitt lining poured, ready for fitting and finishing.

desired dimensions, and then boring out the bearing to the proper size. The other method makes use of the shaft, which is to be supported by the bearing, as a mandrel. Where it is not practical to use the same shaft, a separate mandrel is usually turned up corresponding to the shaft. In the latter method it is only necessary to fit the bearing by scraping. This method is usually employed when replacing line-shaft bearings, where adjustment for aligning is provided. The former method is used for replacing motor bearings or other bearings where greater accuracy is necessary and where no provision for adjustment is made.

526. The Steps In Rebabbitting A Bearing Shell Of A Sleeve Bearing Are: (1) *Removing the old babbitt metal.* (2) *Cleaning and tinning the bearing shell.* (3) *Setting up and preheating.* (4) *Pouring.* (5) *Finishing.* Each of these steps is treated in the following sections.

527. The Old Babbitt Metal Must Be Removed From The Bearing Shell, Before Rebabbitting The Bearing.—This can best be accomplished for the sleeve-type bearing shell by heating it with a torch. Anchor holes are usually provided in the bearing shells (Fig. 302) to hold the babbitt lining in place. Hence, in removing the old babbitt metal from a bearing shell, care must be taken to insure that these anchor holes are thoroughly cleaned out before repouring the babbitt.

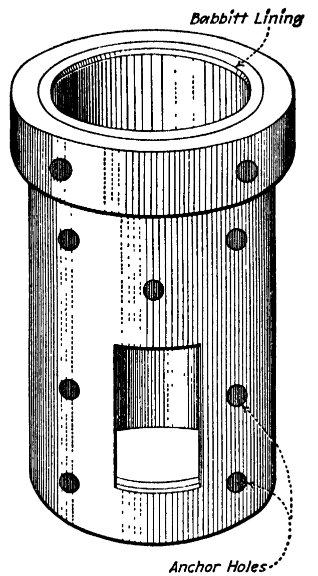

FIG. 302.—A solid-bearing showing the anchor holes through the shell. The babbitt comes through these holes and thus prevents the lining from becoming loosened.

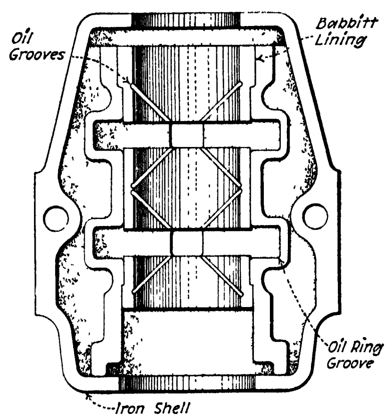

FIG. 303.—Bearing showing oil grooves cut in babbitt lining to aid lubrication.

528. NOTE.—THE ARRANGEMENT OF THE OIL GROOVES AND OIL HOLES SHOULD BE NOTED BEFORE MELTING THE OLD BABBITT FROM A BEARING SHELL.—Figure 303 shows the oil grooves and oil holes in a bearing. To insure their exact duplication in the new bearing it may be desirable to make a sketch of the old bearing.

529. Bearing Shells Must Be Thoroughly Cleaned Before Babbitting.—The shells should be free from sand, scale, rust, oil, and grease. The sand can be removed by a sand blast, wire brush, or by pickling in a hydrofluoric acid solution. When using acid solutions for the removal of sand, rust, or scale from a bearing shell, the acid dip should be followed immediately by a thorough washing in clean water. Should any of the acid solution remain on the bearing shell, during the pouring of the babbitt, it will be impossible to make the babbitt metal stick to the shell.

530. Note.—The Compositions Of The Hydrofluoric And The Sulphuric Acid Cleaning Solutions Are: *Hydrofluoric*—1 gal. of commercial hydrofluoric acid to 10 gals. of water. *Sulphuric*—1 gal. of commercial sulphuric acid to 10 gals. of water.

531. Caution.—Care Must Be Taken In Mixing Acid And Water Solutions.—Always pour the acid into the water, never pour the water into the acid. The acid should be poured slowly into the water and the solution should meanwhile be thoroughly stirred with a wood paddle.

532. Bearing Shells Should Be Tinned Before Being Rebabbitted.—This applies particularly to bronze and steel shells; cast-iron shells are rarely tinned. A bearing shell can be tinned by first covering all parts which are not to be tinned with a clay wash, or a thin mixture of graphite and water. After the clay wash or graphite mixture has dried, swab the parts to be tinned with a solution of zinc chloride. The shell is then immersed in a pot of molten solder, which should be kept at a temperature of approximately 680°F. The shell should be left in the solder until it is hot enough for the solder to run off freely, leaving a thin film. The shell should then be removed from the solder pot and again swabbed with zinc chloride, and again dipped into the molten solder. Should any untinned places remain, this process should be repeated.

533. Note.—Babbitt Metal Should Not Be Used For Tinning, but rather a mixture of 50 per cent tin and 50 per cent lead. The tinning metal should always be maintained at a temperature of approximately 680°F.

534. Bearing Shells And Mandrels Should Be Preheated Before Pouring The Babbitt Metal.—This is necessary to insure that the babbitt will flow close to the shell and adhere

to the surface, and also to permit the shell and babbitt to shrink together in cooling, which prevents the babbitt lining from becoming loose or cracked. Cast-iron shells should be preheated (usually with a blow-torch) to a temperature of about 200°F. Tinned bronze, steel, or malleable iron shells should be poured after the final tinning and at the tinning temperature. If an endeavor is made to preheat a tinned shell, there is always a possibility of burning off the solder.

535. A Bearing Shell Must Not Be Overheated During The Preheating.—If the shell is overheated, the length of time for cooling may be so prolonged, that the heavier metals in the babbitt alloy will have time to settle to the lowest part of the bearings. If this should occur, the metal in one part of the bearing will be soft while that in the other part is brittle. If the shell is too cold when the babbitt is poured, it will cool too quickly, which may cause the babbitt metal to shrink away from the shell.

536. The Babbitt For Small Sleeve-Type Bearings Is Usually Poured Solid And Then Bored Out On A Lathe.—This method is ordinarily used for bearings for shafts up to about 1 in. in diameter. This type of bearing, after being cleaned and tinned, is set up on a level surface. A dam of clay is built around the bottom of the bearing to hold the molten metal in the sleeve. Any other openings in the bearing shell, such as oil holes or oil-ring grooves, must be plugged up with clay to prevent the babbitt metal from flowing out during pouring. The bearing shell is then preheated and the shell filled with babbitt metal.

537. NOTE.—CLAY IS ONE OF THE MOST FREQUENTLY USED MATERIALS TO PREVENT THE MOLTEN METAL FROM FLOWING OUT OF A BEARING SHELL.—However, a mixture of asbestos, putty, and oil will give excellent results as it will not harden like clay. The clay must be softened each time after it is used, but with the asbestos mixture as many as 15 bearings have been run without the further addition of oil.

538. Bearing Shells Which Are Cast Solid Must Be Bored Out And Finished.—This is usually accomplished by placing the bearing shell in a lathe. After it has been trued, it is bored out and finished to fit the shaft which it is to support.

Larger bearings are cast around a mandrel. Bearings of this type are described in the following sections.

539. The Babbitt For Larger Bearings Is Usually Cast Around A Mandrel (Fig. 304).—For motor bearings the mandrel is usually somewhat smaller than the diameter of the shaft. After the bearing has been poured, it is finished to size by boring and scraping. For line-shaft bearings the bearing is usually cast to exactly the shaft diameter and all the finishing that is necessary is a little scraping.

540. NOTE.—IN MAKING MANDRELS, the mandrels should have a diameter somewhat smaller than that of the shaft to which the bearing is to be fitted. This is to allow for finishing the bearing. Figure 305 illustrates a mandrel and surface plate. The cast-iron plate (Fig. 305-*II*) should be 6 or 8 in. square and 1 in. thick. A hole 1 in. in diameter should be drilled in the center to be used in locating and holding the form or mandrel (Fig. 305-*I*). One end of the mandrel is turned down to fit the hole in the plate. The body of the mandrel should be turned down to about $\frac{5}{16}$ in. (diametrically) smaller than the diameter of the shaft. This allows for finishing after the bearing has been poured.

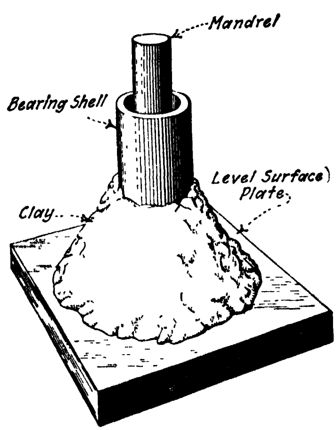

FIG. 304.—Diagram showing method of setting up a solid shell-type bearing preparatory to pouring.

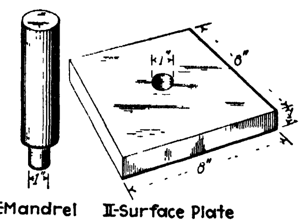

FIG. 305.—Mandrel and surface plate which can be used in the repair of bearings.

541. The "Setting Up" Of A Bearing Shell And Mandrel For Pouring is shown in Fig. 304. After the old babbitt lining has been melted out of the shell, and the shell has been cleaned and tinned, it is ready for setting up prior to pouring the new babbitt lining. For a solid shell-type bearing, (Fig. 302) the bearing shell is slipped over the mandrel Fig. 304, which is

securely held in the flat surface plate. The bearing shell is centered around the mandrel and held in position with clay. With the shell and mandrel in place, preheat (with a blowtorch or gas flame) the shell until the tin starts to melt. The shell is now ready for pouring.

542. NOTE.—THE PROPER OBSERVANCE IN THE DETAILS OF CONSTRUCTION OF A BABBITT BEARING IS AS IMPORTANT AS THE SELECTION OF A GOOD GRADE OF BABBITT.—No matter how good the metal may be, if it is carelessly applied it will sooner or later give trouble. However, good grades of babbitt should always be used. Special alloys may be necessary for important heavy-duty, high-pressure bearings. In some cases it will be found advisable to cooperate with the manufacturer of a machine to obtain his recommendations as to the grade and quality of babbitt which should be used for certain bearings.

543. The Entire Lining Should Be Poured At Once.—When the bearing lining is cast in several pourings, there is the possibility of the "pours" not properly uniting. An imperfect bearing lining may result. It is therefore necessary that the ladle be of sufficient capacity to accommodate the entire pour. The babbitt should be poured quickly to insure a complete union of the babbitt with the shell.

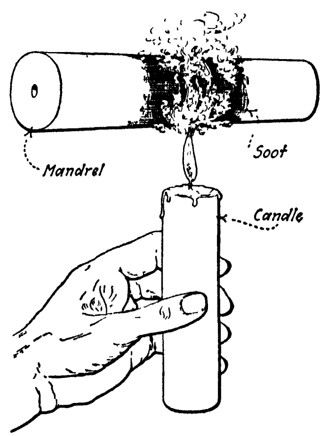

FIG. 306.—Sooting mandrel to prevent it from sticking to the babbitt.

544. NOTE.—TO PREVENT A MANDREL FROM STICKING WHEN POURING A BEARING, the mandrel should be heated and plunged into a solution of clay thinned with water. This will give it a light coat of clay and keep the babbitt from sticking to it. Other methods consist of smoking the mandrel (Fig. 306) or covering it with thin paper. These methods also facilitate the removal of the mandrel after the babbitt metal has set.

545. Bearings Should Be Poured In A Vertical Position Wherever Possible.—Wherever the irregular shape of the bearing makes it inadvisable to pour in a vertical position it

should be inclined to the most convenient angle and poured while supported at that angle.

546. When Pouring A Babbitt Bearing Care Must Be Taken To Prevent Splashing Or The Pocketing Of Air.—The babbitt should be poured from a ladle (Fig. 307) in a steady stream directly down along the mandrel. The lip of the ladle should be kept free from burrs or other surface irregularities to insure the pouring of a smooth, round stream. If the metal is splashed against the mandrel it will cause blowholes and produce a "mushy" bearing.

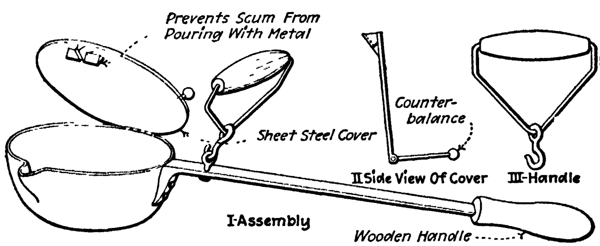

FIG. 307.—Handy ladle for pouring babbitt.

547. NOTE.—CLEAN, MELTING POTS AND LADLES ARE THE FIRST REQUISITES TO SUCCESSFUL BABBITTING.—To clean them thoroughly, they should be heated nearly red-hot and sprinkled with powdered rosin. This will give off a dense white smoke that can be ignited. After it has burned out, the pot or ladle can be brushed off with a cloth and it will be absolutely clean.

548. "Babbitt Metal" Signifies No Definite Composition Of Metals.—Originally babbitt metal had a fixed composition, being composed of 90 per cent tin and 10 per cent copper and antimony. The antimony was used to make the composition expand when it cooled, thus causing the lining to fill the shell. At present, babbitt metals are made up according to some 50 different formulas. However, with the exception of a few cases, babbitt metal can be classified under two groups: (1) *A lead-base alloy.* (2) *A tin-base alloy.*

549. NOTE.—BABBITT METAL WHICH HAS ONCE BEEN OVERHEATED SHOULD BE DISCARDED.—When a babbitt metal has been overheated, part of the constituents are burned out, leaving an improper mixture.

550. Tin-Base Alloys Are The More Generally Used, as experience shows that this type of alloy is less affected by a wide range of temperature during the melting and pouring processes. However, it has been noted that, under certain test conditions, some lead-base alloys make a better showing than the tin-base metals, as to their ability to withstand successive hammer blows. Furthermore, tests show that some lead-base alloys have better anti-frictional properties than have the tin-base alloys.

551. NOTE.—IT IS NOT ADVISABLE TO REUSE BABBITT METAL, WHICH HAS BEEN MELTED FROM AN OLD BEARING.—However, when the practice of reusing old babbitt metal is followed, at least one-half new metal should be used in the mixture. Care should be taken when mixing babbitt metals that no old babbitt metal of unknown composition is melted with any new babbitt metal—and especially with lead-base babbitt—or trouble is likely to result.

552. How Best To Select And Buy Suitable Babbitt Metal is a problem. The babbitt consumer today is confronted with a great variety of babbitts now on the market. In many cases absurd claims are made as to the merits of their products by their manufacturers. Sometimes such claims are set forth through lack of knowledge on the part of the babbitt manufacturer, and occasionally with the express purpose of inducing the customer to purchase an inferior product at what seems to be a very attractive price. It is therefore advisable to consult a recognized manufacturer of babbitt metal when in the market for this material.

553. Tests Have Proved That The Temperature Of Babbitt Metal Plays A Very Important Part In The Production Of Good Bearings.—The correct temperature at which babbitt should be poured is between 460° and 480°C. If the babbitt metal is poured too hot or too cold, it will become either soft or brittle, and will not be uniform in structure. This is of utmost importance when using a metal having a lead base and also applies, though in less degree, to the use of a tin-base alloy.

554. Table Showing The Correct Temperatures For Pouring Babbitt And For Shells, Mandrels, Etc., (J. S. Dean Motor Engineering Dept. Westinghouse Electric Co.).

	Correct temperature, deg. C.	Do not exceed deg. C.
Tinning allow..................	410–440	450
Mandrels:		
For tinned solid-bronze shells ...	100–125	
For tinned split-bronze shells.....	125–150	
For split or solid-iron shells.....	240–270	
Shells:		
Iron..........................	200–250	
Bronze........................	See Note[1]	
Babbitt.......................	460–482	490

[1]Temperature of tinning alloy

555. Note.—The Results Of Pouring A Lead-Base Bearing Metal At Improper Temperatures Is Graphically Shown In Fig.

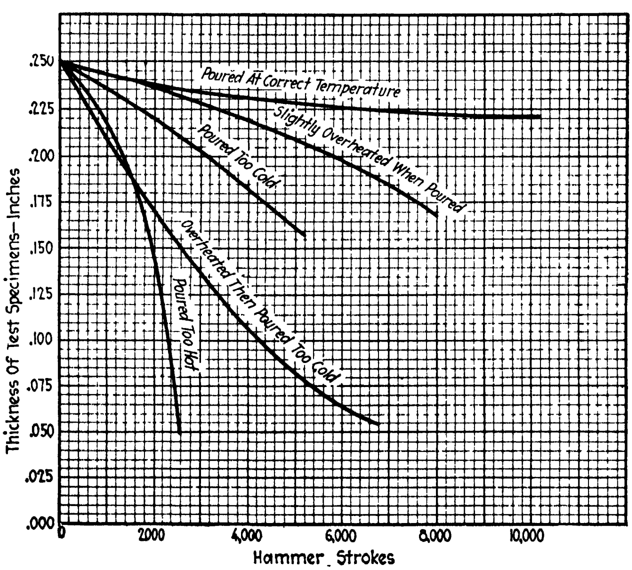

Fig. 308.—Chart showing the results of pouring a lead-base bearing metal at improper temperatures. (J. S. Dean, *Electrical World*, Oct. 22, 1921.)

308. Test samples of the metal were obtained by pouring at different temperatures and under various conditions. These samples were then subjected to hammer tests and the results from these hammer blows were observed and plotted.

556. Various Methods Are Employed For Determining The Proper Melting Temperature Of Babbitt Metal For Bearings. The most accurate method for determining the temperature is by the use of a pyrometer (Fig. 309). This instrument usually consists of a thermocouple and a milli-voltmeter.

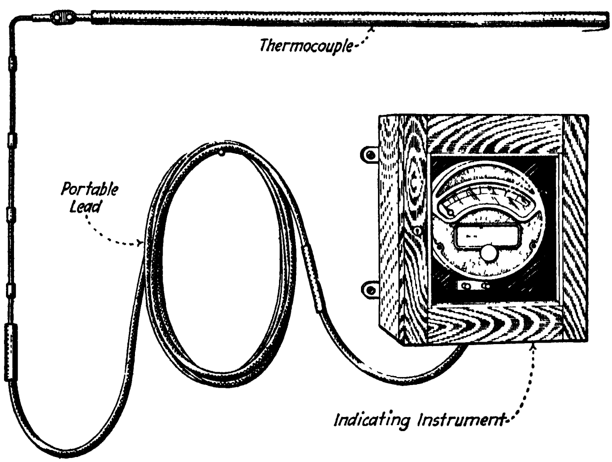

FIG. 309.—Illustrating the Model 162 Bristol's Electric Pyrometer. It is of the low resistance type suitable for temperatures up to 2000° F for continuous service or 2500° F for intermittent use. (THE BRISTOL COMPANY, Bulletin No. 274.)

The thermocouple is sealed in a clay tube and fitted with leads for connection to the milli-voltmeter, which is calibrated to read in degrees Fahrenheit or Centigrade. By immersing the tip of the thermocouple into the molten metal, the temperature is indicated on the instrument. The more modern industries are fitted with this type of temperature indicator, while the smaller shops and repair departments resoit to the pine-stick method of determining the correct pouring temperature of the metal.

557. NOTE.—IN THE PINE-STICK METHOD the stick is inserted into the melted metal and if the metal is at the proper temperature the stick

will become charred to a fairly dark-brown color; if it chars black or burns, the metal is too hot.

558. Note.—The Pine- Or Birch-Stick Method Of Determining The Temperature Of Babbitt Metal Is Very Uncertain.—It is almost impossible to predetermine accurately the temperature at which such a stick will blacken. The moisture content of the stick will vary and this will change the temperature required to blacken it. By actual test it was found that the temperature of a babbitt metal varied over a range of 75°F. when using the pine- or birch-stick method of temperature measurement.

559. Faulty Bearings Are Frequently Caused By Pouring The Babbitt Metal At Too High Or Too Low A Temperature.—If the babbitt is too cold, it pours thick and heavy and the metal will set before it can fasten itself to the bearing shell. If the metal is too hot when poured, it will produce a loose-grained lining which will break under impact. If difficulties are encountered, the correct temperature at which to pour the metal should be obtained from the manufacturer of the metal—and it is well to obtain this information in any case.

560. Note.—The Pouring Temperature Of A Babbitt Metal Means The Temperature Of The Metal In The Ladle As It Is Being Poured.—The temperature of the metal is frequently measured or otherwise determined in the melting pot. It does not take long for a metal to drop 100° after it is dipped out of the melting pot. Hence, if the bearing is poured at a distance from the pot, the drop in temperature in handling it may be sufficient to affect the quality of the lining. It is therefore advisable to pour the bearings in close proximity to the melting pot. Where conditions make it necessary to carry the molten metal a considerable distance, an allowance may be made by heating the metal in the pot to a higher temperature than that desired for pouring. This, however, should not be done except where necessary, since overheating the metal may destroy its quality, as explained in Sec. 549.

561. Babbitt Metal Should Be Thoroughly Stirred During Melting.—This is to prevent the heavier metals of the alloy from settling to the bottom of the melting pot. When dipping a ladle of metal from the melting pot, the ladle should be dipped into the bottom of the pot, thus mixing the metal before removing any.

562. Note.—To Prevent The Formation Of A Dross On The Surface Of Melting Babbitt Metal, it should be covered with a layer, about ⅛ in. thick, of powdered charcoal or graphite. Where such a layer is present, the oxide dross cannot form.

563. After Bearing Sleeves Have Been Poured, They Must Be Fitted.—This operation usually consists in boring out, cutting oil grooves (Fig. 310), drilling oil holes, and scraping. When the shaft, to which the bearing is to be fitted, is not worn, it is frequently unnecessary to do any scraping. After the bearing has been finished, it is assembled into the bearing housing and given its initial run. The bearing should be watched carefully and supplied with plenty of good lubricating oil. Should excessive heating develop, the bearing should be removed and carefully examined to determine the cause of the trouble.

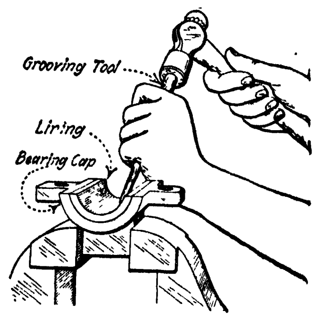

FIG. 310.—Chiselling out oil grooves in one half of a split type bearing.

564. NOTE.—THE PROPER AND IMPROPER METHODS OF CUTTING OIL GROOVES IN BEARINGS ARE SHOWN IN FIG. 311.—The proper method of cutting oil grooves is shown at *I* (Fig. 311), while *II* (Fig. 311) illustrates the improper method. At *II* (Fig. 311), no drain grooves or holes are provided. Figure 311-*I* shows the bearing with drain grooves and a drain hole drilled in the lower portion of the drain grooves. These holes and grooves permit the oil to flow back into the oil well.

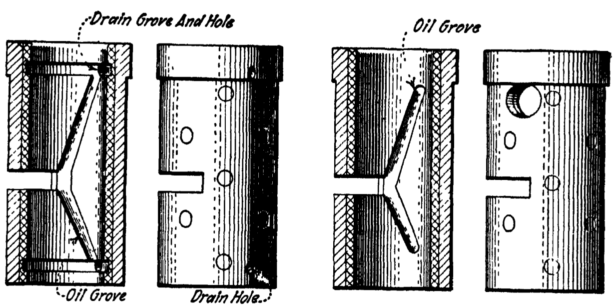

FIG. 311.—Illustrating the proper and improper methods of cutting oil grooves in bearings.

565. Oil Grooves In Bearings Should Be Employed Only When Conditions Are Abnormal.—For ordinary everyday practice there is no necessity for grooves. The factors that

influence the lubrication of bearings are as follows: (1) *Size.* (2) *Speed.* (3) *Temperature.* (3) *Method of application of lubricant.* (5) *Pressure.* (6) *Mechanical conditions such as* design, proportions, fit, etc. When all these factors are considered, the correct lubricant can be provided and it is seldom that oil grooves will be required to assist the lubrication. Heavy bearings, and those which operate at slow speeds, high pressures, and high temperatures, must be lubricated with a heavy-body oil; light-body oils will not satisfactorily serve bearings of this type. The body of an oil has much to do with the formation and maintenance of the film previously referred to (Sec. 481). However, all the factors must be considered before the proper oil can be selected for a bearing.

566. NOTE.—THE FOLLOWING POINTS SHOULD BE OBSERVED IN FITTING BEARINGS: (1) *Avoid sharp edges or corners on the grooves,* which might scrap the oil from the shaft as it rotates. (2) *Do not cut oil grooves through the end of a box,* as this will allow the oil to run out. (3) *See that the bearing and shaft are in perfect alignment.*

567. Sleeve Type Bearings Are Usually Bored And Finished To Fit, Requiring Little Or No Scraping (Fig. 312).—If after the bearing is assembled in the housing, heating develops, then the bearing should be removed and inspected for irregularities in its bearing surface. If there are indications that the bearing bears only in spots, these spots should be scraped out until the entire bearing surface bears upon the shaft.

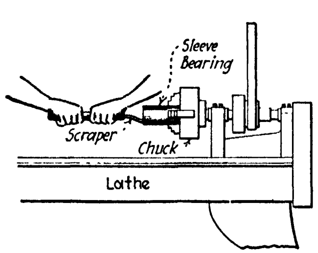

FIG. 312.—Scraping a sleeve type bearing.

568. NOTE.—THE OBJECT OF SCRAPING A BEARING IS TO FIT THE BEARING ACCURATELY TO THE SHAFT BEARINGS, which have had their linings poured directly around the shaft which they are to support, nearly always require scraping. Bearings which are poured around a mandrel and then bored and reamed to the correct diameter, frequently fit without scraping.

569. Effective Bearing Scrapers Can Be Made From Old Files.—The scrapers shown in Fig. 313-*I* and -*II* may be made

from three-cornered files, and the third, Fig. 313-*III*, may be made from a half-round file. The scraper shown in Fig. 313-*I* is hollow ground. To make it first grind off the file teeth on an emery wheel and then grind the sides concave. The scraping edges should then be finished on a bench stone. The other two scrapers can be made in the same manner, except that none of their surfaces is hollow ground.

570. Worn Bronze Bearings Can Usually Be Put Back Into Service By Boring Out And Babbitting Them. When a brass or bronze sleeve bearing becomes worn down too far for satisfactory use, it may be bored out and babbitted. It is then rebored and fitted to the shaft and will generally give service equal to that of a new brass or bronze bearing.

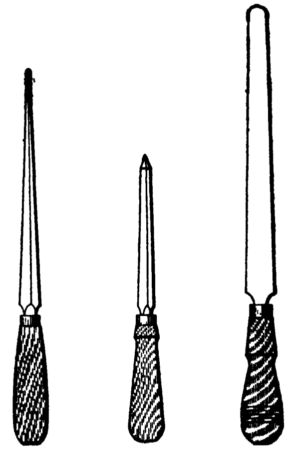
I-Three Cornered II-Three Cornered III-Half Round

FIG. 313.—Scrapers made from old files.

571. The Steps In Rebabbitting A Split Bearing Are: (1) *Remove the bearing from the housing.* (2) *Remove the old babbitt from the bearing shell.* (3) *Clean and tin the bearing shell.* (4) *Set up the bearing shell preparatory to pouring.* (5) *Pour.* (6) *Fit.* Each of these steps is explained in following sections.

572. A Split Bearing Can Usually Be Removed From The Bearing Housing With Little Difficulty.—The housing which holds a bearing of the split type is usually constructed in such a manner that it can be separated. This facilitates the removal of the bearing. Figure 314 shows one-half of a standard split bracket and illustrates the bearing housing construction.

573. NOTE.—A BEARING OF THE SPLIT TYPE CAN SOMETIMES BE REMOVED FROM ITS HOUSING WITHOUT DISTURBING THE BELT OR PULLEY (Fig. 315).—This operation consists of removing the top half of

the bracket (if it is of the split bracket type of construction) or the top half of the bearing housing. A jack is placed under the pulley to release the weight of the rotor from the lower half of the bearing shell. The belt strain is releaved by a brace or prop. The bearing shell can then be removed by slipping it around from under the shaft.

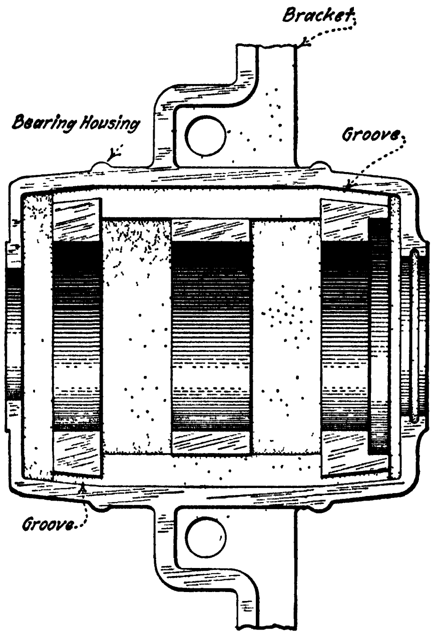

FIG 314.—Illustration showing one-half of a standard split bracket with grooves in the bearing housing walls to prevent leakage of oil at the split. (*Industrial Engineer*, March, 1924.)

574. The Removal Of The Old Babbitt Lining From A Split Type Bearing Can Be Effected With A Cold Chisel (Fig. 316).—This is accomplished by driving the chisel between the lining and the inner wall of the bearing shell. Frequently the entire lining can be removed in one piece.

575. The Melting-Out Process For Removing Old Babbitt Linings Is The One Most Generally Used (Fig. 317).—A blow-torch or gas flame can be employed for this purpose, following the same procedure as for sleeve bearings as described in Sec. 527.

576. The Cleaning And Tinning Of Split-Type Bearings Are The Same As That For Sleeve-Type Bearings (Sec. 529).—A concentrated caustic soda solution is also effective for removing grease and oil from bearing shells. However, this method

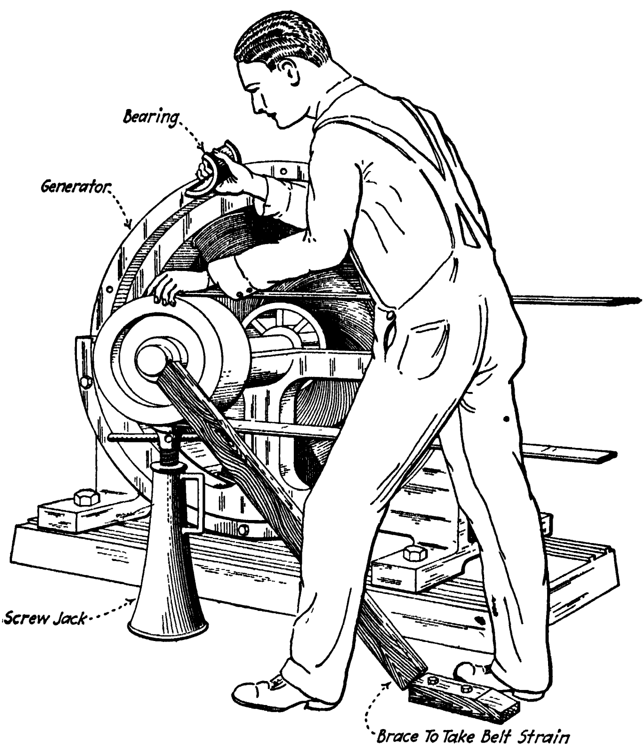

FIG. 315.—Diagram illustrating method of removing the bearing from a motor or generator without disturbing the belt. A jack is placed under the pulley to support the weight of the armature, and a brace or prop is arranged to take the belt strain.

does not thoroughly remove the grease and dirt which has been burned into the metal bearings which have run hot in service.

577. To Set Up A Split Bearing Preparatory To Pouring, proceed as follows (Figs. 318–319). Provide two wooden or steel half rings to be fitted into the flanges at the ends of the bearing shells; these half rings are to support the mandrel.

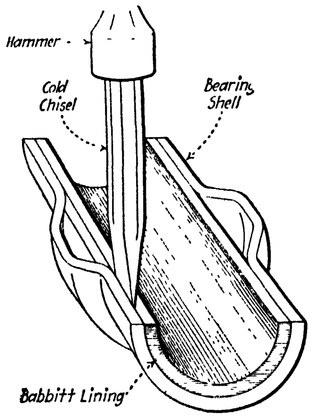

FIG. 316.—Removing the babbitt lining from a split-type bearing, using a cold chisel and hammer.

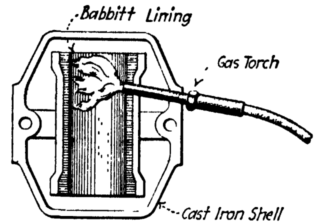

FIG. 317.—Removing the babbitt from a bearing shell by melting.

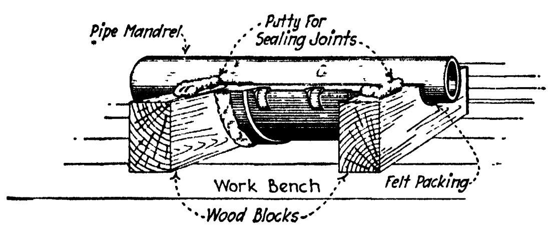

FIG. 318.—Method of setting up a small split bearing before pouring the babbitt.

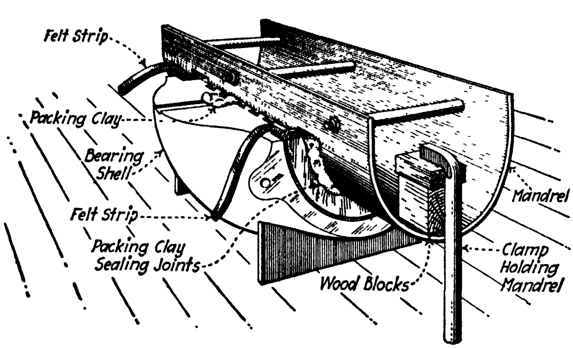

FIG. 319.—Method of setting up a large bearing cap prior to pouring of the babbitt.

Strips of felt or asbestos are then placed between the rings and the mandrel. Seal all the joints on the outside with clay. The mandrel must be clamped securely (Fig. 319) to the shell to prevent any displacements when pouring the babbitt. In Fig. 318 is shown a small bearing with its mandrel and packing rings before pouring the babbitt. The mandrel in Fig. 318 consists of a piece of pipe which has a diameter slightly less than that of the shaft to which the bearing is to be fitted.

578. Mandrels For Large Bearings Can Be Made By Forming A Piece Of Sheet Iron To The Desired Curvature, as shown in Fig. 319. This is a quick and convenient method of making a mandrel for a bearing for a large shaft.

579. NOTE.—NEVER POUR BABBITT INTO A SHELL THAT CONTAINS ANY MOISTURE.—See that the surface of the clay used for sealing the joints or damming, is dry, before pouring the babbitt metal. Many serious burns have resulted from failure to observe these precautions.

580. Tamp The Babbitt Down Lightly With The Ball End Of A Hammer As Soon As The Bearing Shell Has Been Poured.—This will remove any blowholes that may have formed. This must be done before the babbitt sets; otherwise the tamping will be ineffective.

581. NOTE.—THE LADLE SHOULD HAVE A SMOOTH, ROUND LIP Fig. 307).—It should be free from burrs or other irregularities. All of these defects prevent the babbitt metal from flowing in a steady stream which is necessary to obtain the best results. If the stream is broken during the pouring, joints are formed, which are undesirable. The bearing should set for 15 or 20 min., after pouring, before the mandrel is removed.

582. After The Babbitt Metal Has Cooled And The Mandrel Has Been Removed, The Bearing Is Ready For Fitting And Finishing.—In rebabbitting a bearing of the split type, the castings usually close in across the joints. Rough bore the bearing to within ⅛ in. of the shaft size, then caliper the diameter of the ball. If it is found to be out of round or small across the joints, it may be corrected by peening the finished boring. True up the bearing very carefully in relation to the ball.

583. To Scrape And Finish A Split-Type Babbitt Bearing, proceed as follows: The lower half of the bearing is assembled in its housing. The shaft is given a thin coat of Prussian blue

paint or of a mixture of lampblack and oil. The upper half of the bearing is assembled into place. The shaft is turned several revolutions to spot or mark the bearing. The bearing halves are then removed and examined for spots. The spots (Fig. 320), which show paint, are scraped down with a scraper (Fig. 313). If the paint has been removed only in spots, it indicates that the bearing is contacting only in spots. After these spots have been scraped down, the bearing is replaced in the housing and the paint-coated shaft again rotated in it. The bearing is continuously scraped and refitted until the

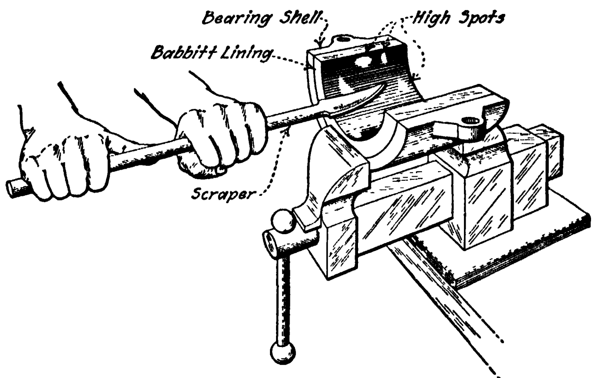

Fig. 320.—Illustrating the method of scraping a split type bearing. (*Southern Engineer.*)

entire surface of the bearing bears on the shaft. When the paint has been evenly distributed over the entire surface of the bearing it indicates that all of this surface is contacting with the shaft.

584. The Bearing Should Be Carefully Watched During Its Initial Run After Rebabbitting.—Should the bearing heat, it should be taken apart and inspected for black spots. It is necessary to scrape out these spots so that the entire surface of the bearing is active. The application of Prussian blue to the bearing will show up the high spots. If Prussian blue is not available, apply a light coat of oil mixed with lampblack to the shaft. After rotating the shaft the lampblack will

catch on the high spots of the babbitt. The operation of fitting and scraping should continue until a smooth bearing is obtained.

585. The Recommendations Of The Westinghouse Company As To Babbit-Methods And Equipment are contained in the following material which appeared in *Electric Journal* for October, 1924. While these data relate particularly to bearings for street-railway motors, the information which they give applies, in general, for motors for any service whatsoever.

586. GOOD BABBITT METAL AND ADEQUATE EQUIPMENT ARE ESSENTIAL.—Not only is it of the utmost importance to use a good grade of babbitt metal when relining motor bearings, but it is essential to have this metal, while being worked, kept within certain definite ranges of temperature. This means that the babbitt melting pots should be equipped with temperature indicating devices—preferably with automatic temperature control—to get the best results. In addition, the workmen should be supplied with the necessary detail equipment. Further, they should be carefully instructed as to the proper methods to use in connection with this work.

587. SEVERAL BABBITTING POTS MAY BE DESIRABLE.—An up-to-date equipment to handle the babbitting of motor and car journal bearing shells in railway shops should consist of at least three pots, to be used somewhat as follows:

Pot 1.—For melting babbitt out of old bearing shells. Further, this pot of metal to be used to reline motor-axle and car journal bearings, provided the metal is of one grade.

Pot 2.—For half-and-half solder which should be used in connection with the tinning of bronze and malleable iron bearing shells.

Pot 3.—The new tin-base babbitt metal to be used for relining all armature bearing shells.

The above arrangement of pots permits the use of new metal in relining the armature bearings and the use of the old reclaimed metal in connection with the work on the motor-axle and car journal bearings.

588. THE BEST METHOD FOR HEATING THE BABBITT METAL will depend upon the available equipment and the most economical fuel supply; the melting pots may be heated by any of the following methods:

1. *Coke or Coal.*—This method of heating requires considerable attention to maintain the desired temperature and does not lend itself to good regulation or control of temperature, hence is not used in many shops.

2. *Gas and Air.*—Pots heated by gas and air are used quite extensively as the heat can readily be controlled. Further, with this method of heating the automatic temperature control feature can be successfully

applied so that the correct working range of temperature can be obtained, thus eliminating all guesswork.

3. *Oil.*—This method of heating is not in general use. However, oil burners are used in a number of heating applications and undoubtedly could be applied successfully to babbitt pots.

4. *Electricity.*—Electrically heated babbitting pots are now being used successfully. Some of the advantages of this method of heating are:

a. Quick melting of the babbitt metal.

b. Automatic temperature control maintains the temperature of the metal within the correct limits.

c. The metal is not subjected to injury by overheating.

d. Connections are easily made so that the pots can be located at any point in the shop without reference to pipe lines.

e. The electric melting pot occupies a minimum floor space.

f. Thick heat insulation gives low cost of operation and insures a cool working pot.

g. They may be operated on 500 volt direct-current from the trolley line, which is always available in railway shops.

589. LADLES of sufficient size should be provided to hold enough babbitt to reline the bearings with one filling. This would mean at least three different sizes of ladles to pour the small, intermediate and large bearing shells found on the average railway property. These ladles should be of the self-skimming type fitted with inside bridges so that the metal is taken from the bottom of the ladle while pouring. Hand leathers should be supplied for the workmen to facilitate handling the ladles of hot metal. Ladles that are fitted with loose malleable iron sleeves on the handles can be safely handled without the use of leathers.

590. JIGS AND FIXTURES promote economical production. A complete set of babbitting fixtures to hold each type of shell while pouring the metal is necessary to turn out satisfactory relined bearings at a minimum cost. The first cost of well-designed babbitting fixtures may seem high and a needless expenditure of money, but in the end they will save money for your company. Experience has shown that relined bearings made with poor fixtures require considerable finishing to put the bearings in good working condition. The money thus spent would in a short time more than pay for a set of fixtures that would enable your workmen to turn out a good babbitting job at the minimum cost.

591. SUITABLE EQUIPMENT IS REQUIRED TO CLEAN THOROUGHLY ALL BEARING SHELLS before they are tinned. Some of the various cleaning methods found to give satisfactory results are as follows:

1. *Sand Blasting.*—This thoroughly cleans the shells of all grease and grit and, further, it removes any burned parts of the metal, thus making a clean and satisfactory job.

2. *Cleaning Solution.*—Concentrated caustic soda solution is used in a number of shops to clean the grease and oil from old bearings. This method does not thoroughly remove the grease and dirt burned into the metal found on shells that have run hot in service.

3. *Grinding.*—A small abrasive grinding wheel, either stationary or portable, has been used to advantage to remove the burned sections from old bearing shells. This is used in connection with method 2.

4. *Pickling Solution.*—Iron and steel shells may be thoroughly cleaned preparatory to tinning by pickling in a weak solution of sulphuric acid. (See Railway Operating Data for August, 1921, "Tinning Malleable Iron Bearing Shells".)

592. Experience Has Proved That No One Type Of Bearing —Either Ball Or Friction Metal—Is Suitable For Use In All Kinds Of Service.—Ball bearings have their field, in which they are particularly suitable. Some of the arguments

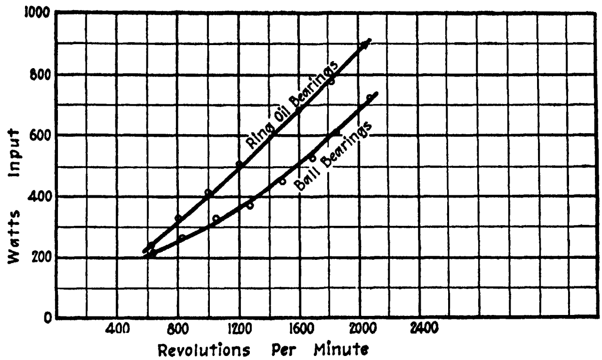

FIG. 321.—Graph showing the results of a test on two motors which were alike except that one was equipped with ring-oiled bearings and the other with ball bearings. The two motors were alternately driven by a third motor. The watt input represents the windage and friction losses of both driven and driving motor, but since the latter was used in both cases, the difference in the losses represents the saving in power from decreased friction, required to drive a ball-bearing motor as compared to a ring-oiled bearing. (*Industrial Engineer*, Sept., 1922, taken from a bulletin issued by the *S. K. F. Industries, Inc.*)

advanced in favor of ball bearings are: Increase in efficiency (Figs. 321, 322, 323, 324, 325, 326 and 327), adaptability to machines constructed with small air-gap clearances, freedom from seizing the shaft when subject to the abuses of tight belts and overload, and reduced maintenance cost.

593. Whether A Ball Bearing Is Superior To A Bronze Oil Bearing, Or Vice Versa, Is Still A Subject Of Controversy.— A consideration of the advantages of each type of bearing discloses its peculiar adaptability to different services, but such

advantages should not be confused. For example, the use of ball bearings, as frequently stated, and which is true, requires less supervision. The answer to such a claim would be that

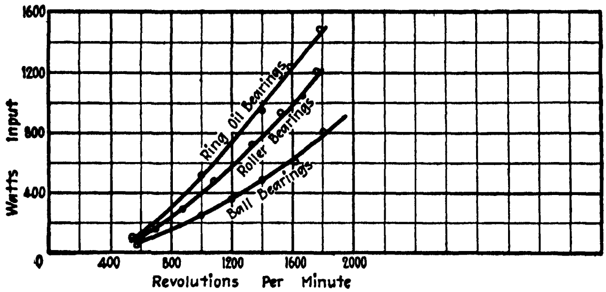

FIG. 322.—Graph showing the windage and friction losses on three motors of similar rating and identical except for the bearings. The losses of the driving motor have been deducted from the watts input, although the losses shown include those occasioned by the driving belt. (*Industrial Engineer*, Sept., 1922, taken from the bulletin issued by *S. K. F. Industries, Inc.*)

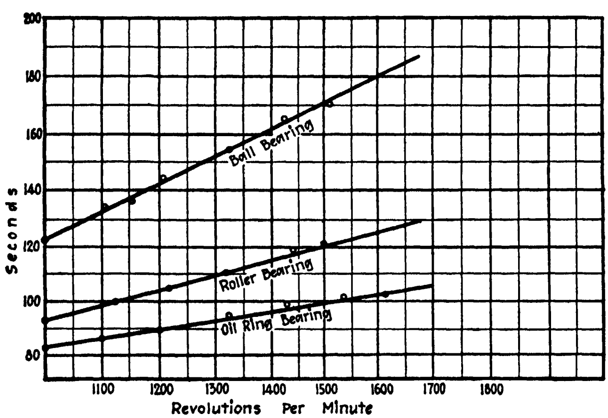

FIG. 323.—Graph obtained by determining the number of seconds the armatures of the three motors used in the previous test rotated after the power was cut off. (*Industrial Engineer*, Sept., 1922, taken from a bulletin issued by the *S. K. F. Industries, Inc.*)

all electrical apparatus in any industrial plant should be subject to a reasonable amount of inspection, hence the substitution of ball bearings would not effect a great deal of maintenance saving.

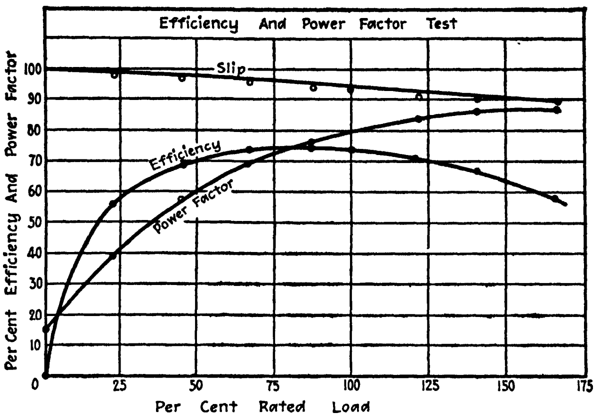

FIG. 324.—Graph showing the efficiency and power factor curves obtained from tests on a 1-hp., ball-bearing induction motor. The power factor exceeds 80 per cent at all loads in excess of 90 per cent of the normal rating. The efficiency is highest at about 85 per cent of the rated load although it reaches 75 per cent or higher with any load between 63 and 113 per cent of rated load. (*Industrial Engineer*, Sept., 1922, taken from a bulletin issued by the *S. K. F. Industries, Inc.*)

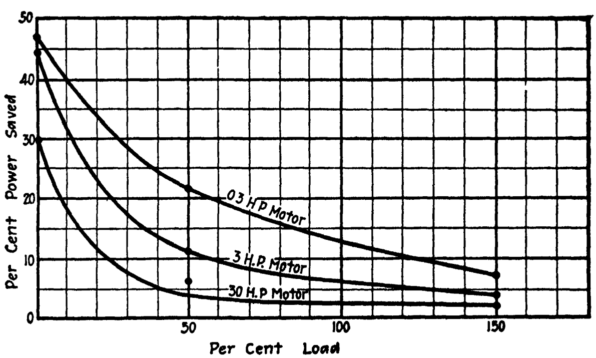

FIG. 325.—Graph showing the percentage of power saved at various loads with motors of 0.3 hp., 3 hp., and 30 hp., respectively, through the use of ball bearings, as compared with plain bearings. (*Industrial Engineer*, Sept., 1922, taken from a bulletin issued by the *S. K. F. Industries, Inc.*)

594. Ball Bearings Have Been Adopted As Standard Equipment By Some Motor Manufacturers.—Other manufacturers furnish motors with ball bearings for special purposes. Many arguments for and against ball bearings are advanced. Both the ball and the sleeve bearing have their particular applications. Figure 328 shows the general practice in mounting ball bearings in motors.

595. Service Is The Prime Requisite Of Any Apparatus In An Industrial Plant.—In order to have dependable and quick repair service, it is necessary to have a stock of all sizes of bearings on hand to suit each make and size of motor. With

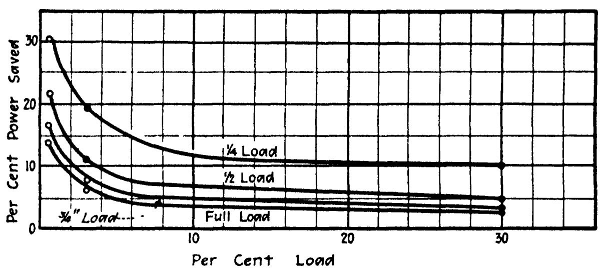

FIG. 326.—Graph showing the saving in power which may be expected with any motor up to 30 hp., at any per cent load, when ball bearings instead of plain bearings are used. These curves were plotted from the results shown in Fig. 325. (*Industrial Engineer*, Sept., 1922, taken from a bulletin issued by the *S. K. F. Industries, Inc.*)

ball bearings, the value of such stocks would amount to considerable sums especially where the maintenance of several hundred motors of varied sizes is considered. In many plants the sizes of motors may range anywhere from 100 hp., down to ¼ hp. and generally include a goodly selection from all the leading manufacturers. With standard bronze bearings made from generous patterns that allow machining to a number of motor sizes without the necessity of cutting too much metal away a comparison of first and maintenance cost of bronze bearings as against that for the ball bearings will usually show a considerable saving in favor of the bronze bearings.

596. Ball-Bearing Lubrication Is Necessary Mainly To Prevent Skidding Or Sliding Of The Balls.—Skidding or sliding of the balls results in the flattening or scoring of the

curved surfaces of the balls. The lubricant also protects the parts from corrosion and conducts any heat away. The lubricant should possess sufficient body to insure rolling of the balls but should not be viscous enough to retard them materially or to cause sliding. Moisture in the lubricant or

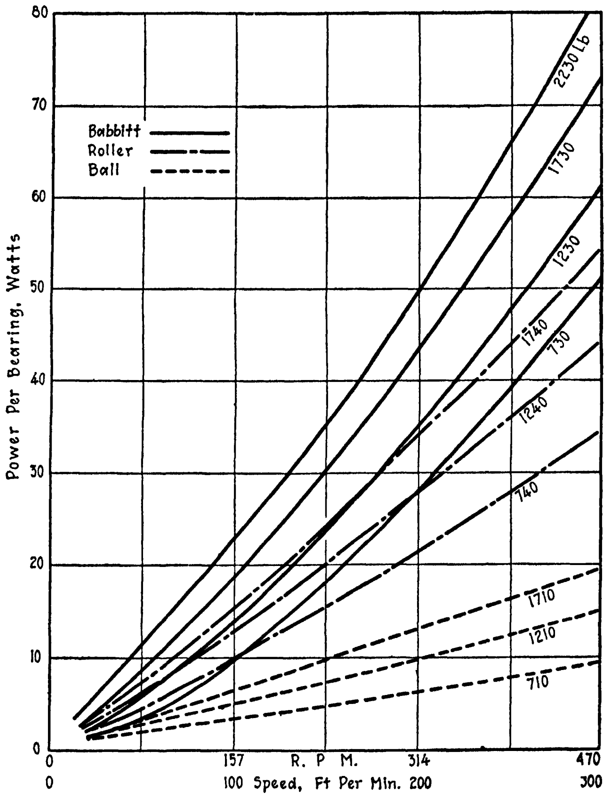

FIG. 327.—Graph showing how the power consumed by friction of bearings varies at different loads and speeds. The data from which these curves were plotted were obtained from recording watt-hour meter readings of a motor driving a long shaft which was equipped first with ring-oiled babbitt bearings, then with ball bearings. The tests were made at a temperature of 100 deg. F. (*Industrial Engineer*, June, 1922.)

its tendency to absorb moisture, will prove injurious to the bearing. The lubricant must also be free from acids or other substances which can cause etching or corrosion of the parts.

597. Care Should Be Exercised In The Assembly Of Ball Bearings On A Shaft.—Figure 329 illustrates the correct and incorrect methods of putting ball bearings on a shaft. Pound-

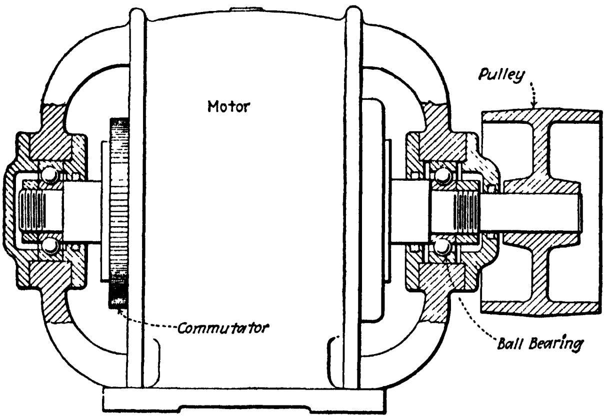

FIG. 328.—An accepted practice in the mounting of ball bearings in motors.

ing on the outer race of a ball bearing (Fig. 329-*I*) is liable to distort or otherwise injure the bearing. This method also tends to force the bearing on the shaft unevenly which will

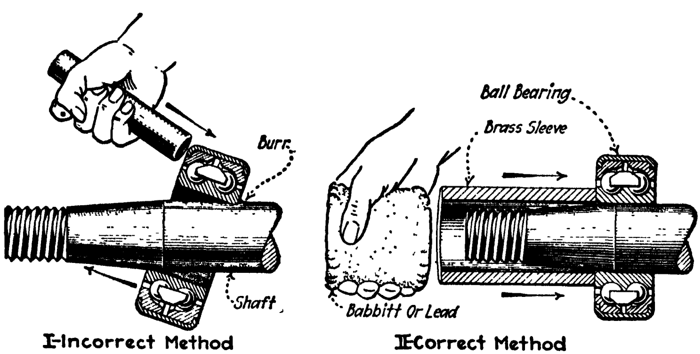

FIG. 329.—Illustrating the incorrect and the correct method of putting ball bearings on a shaft.

score or burr the shaft. The correct method is shown at *II* Fig. 329. It consists in pounding on a brass tube which is large enough to slip over the shaft and which bears evenly all around against the inner race of the bearing.

598. Frequently A Plain Bearing Motor Can Be Fitted With Ball Bearings.—Figure 330 illustrates the details of a 10-hp., motor housing before and after the installation of ball bearings.

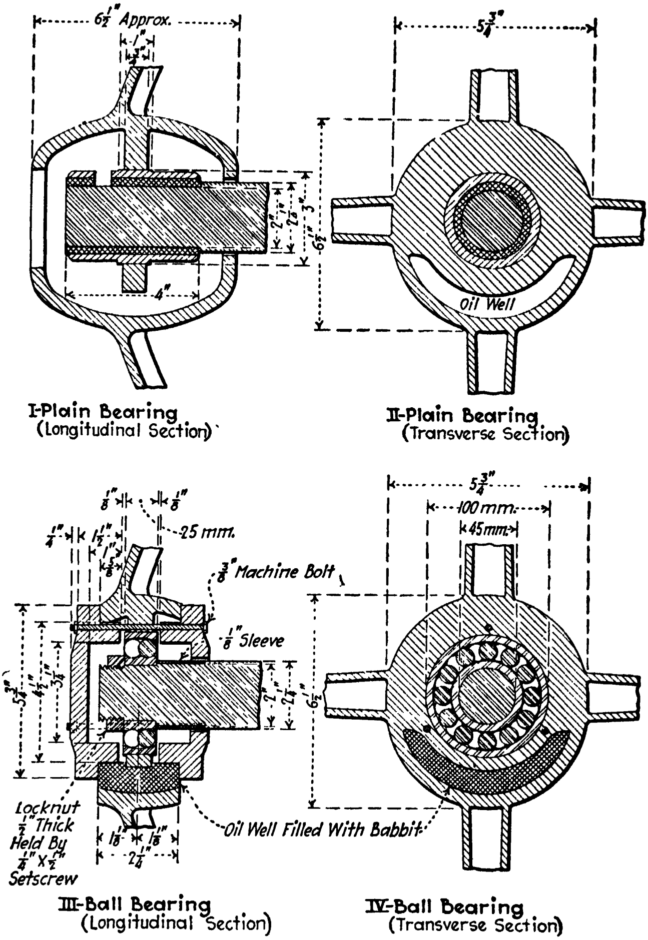

Fig. 330.—Details of a bearing housing of a 10-hp. motor before and after installation of ball bearings.

The bearing housing was cut off and the oil well filled with hard babbitt. The housing was then bored out to the proper size to receive the ball bearing. The shaft was turned down to

fit the ball bearing. A thread was cut on the shaft to fit a lock nut which holds the bearing on the shaft. A set screw prevents the lock nut from working loose.

599. NOTE.—BALL BEARINGS OF THE OPEN AND CLOSED TYPE ARE SHOWN IN FIG. 331-*I* and -*II*.—The open-type ball bearing (Fig. 331-*I*), has one of the shoulders of the outer race ground away so that the bearing can be easily disassembled. The bearing shown at *II* is assembled at the

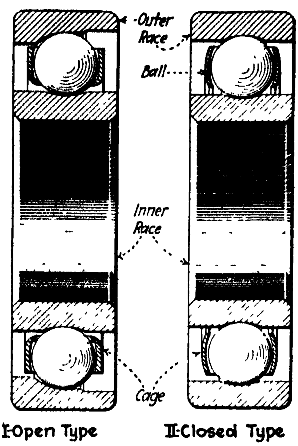

FIG. 331.—Sectional views of ball bearings in general use.

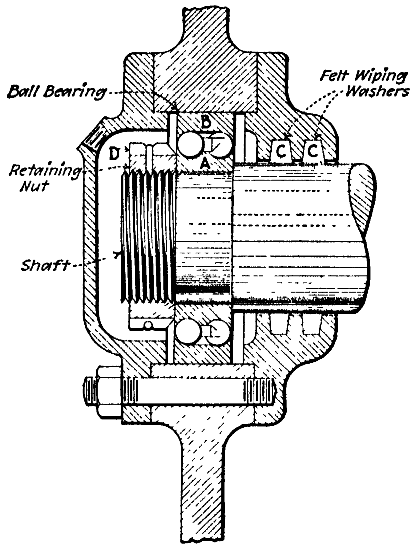

FIG. 332.—Cross section of the bearing and housing of a motor ball bearing.

factory and cannot be taken apart without cutting the rivets, which are employed in some designs, to hold the two halves of the cage together.

600. Ball Bearings May Be Grouped Under Three General Classes: (1) *Radial.* (2) *Thrust.* (3) *Combination.* Each of these types will be described in the following sections.

601. The Radial Type Of Ball Bearing Is Used On Motors Where The Load Is Radial To The Shaft.—A radial load is one which is at right angles to the shaft. Belted, chain-driven, and geared drives are examples of radial loads. Figure 332 illustrates a motor bearing equipped with radial type ball bearings.

602. NOTE.—MOST RADIAL-TYPE BALL BEARINGS ARE CAPABLE OF RESISTING A THRUST LOAD IN AT LEAST ONE DIRECTION.—The amount of thrust which can be sustained varies with the make of the bearing. This amount ranges from 10 to 200 per cent of the radial load rating. However, before subjecting a radial ball bearing to a thrust load of any consequence, the recommendation of the manufacturer should be obtained.

603. Thrust Ball Bearings Are Used Where Heavy Thrust Loads Are Encountered.—Thrust ball bearings (Fig. 333) consist essentially of two or more flat races, usually with grooves ground in the faces, between which are mounted a number of balls held in a suitable cage or retainer, the exact

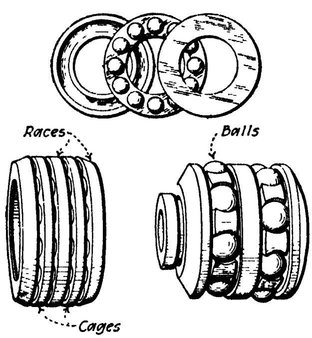

FIG. 333.—Illustrating several types of thrust ball bearings.

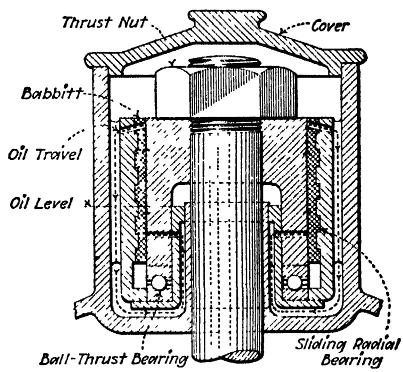

FIG. 334.—Cross section of a ball-thrust bearing.

design of which varies with the different manufacturers. Figure 334 shows the application of a ball thrust bearing to a vertical motor.

604. A Combination Ball Bearing Is Manufactured.—This type of ball bearing combines, in one unit, the essential features of both the radial- and the thrust-type of bearing. Thus a combination-type ball bearing can be used where it would otherwise be necessary to employ separate bearings—one radial-type and one thrust type bearing—to take the load.

605. Ball-Bearing Lubrication is essential. However, after the bearings have been properly installed, it is necessary to lubricate them only three or four times a year. The bearing

housings are provided with reservoirs of sufficient capacity to hold several months supply of the grease lubricant.

606. NOTE.—CAREFUL ATTENTION MUST BE GIVEN TO THE SELECTION OF LUBRICANTS USED WITH BALL BEARINGS, inasmuch as the maximum usefulness of these bearings is obtained only so long as the balls remain in perfect condition. Lubrication is necessary mainly to prevent skidding or sliding which will produce flattening or scoring of the curved surfaces. The lubricant also conducts any heat away from the bearing and protects the parts from corrosion.

QUESTIONS ON DIVISION 5

1. Why is proper maintenance of electrical equipment so important?

2. How frequently should electrical equipment be inspected?

3. Describe briefly the organization necessary for the maintenance of the electrical apparatus of a plant having approximately 1,500 motors ranging in size from 200 hp. down to ¼ hp.?

4. For what should an electrical machine be examined during the inspection?

5. How should the inspections be recorded?

6. What items should an inspection card contain?

7. What conditions should be noted when an inspection is made?

8. What are some of the causes for high bearing temperature? What are the remedies for the causes?

9. How are motor bearings lubricated?

10. What are the limits of clearance in small-sized bearings intended for high speed?

11. What is the purpose of oil grooves in the sides of a bearing?

12. How can the effectiveness of bearing lubrication be determined with an electric circuit? Make diagram.

13. What are some of the causes for leaky bearing housing? How are these causes remedied?

14. Describe some of the causes of bearing heating.

15. What usually causes excessive frame temperatures?

16. How can the correct temperature of the frame of an electrical machine be determined?

17. How do poor electrical connections usually manifest themselves?

18. Why is cleanliness of electrical apparatus so important?

19. What is the best method to use for cleaning electrical equipment? What are the disadvantages in using compressed air for this purpose?

20. How does the air gap vary with different sizes and types of electrical machines?

21. How is the air gap of a machine determined by the inspector?

22. What precautions should be taken in gaging the air gap of a belted machine?

23. How does an uneven air gap effect the machine?

24. What are the two main causes for vibration of an electrical machine?

25. How is the unbalance of an electrical machine determined and corrected?

26. What are the most common mechanical troubles which occur in rotating electrical machinery?

27. What are some of the causes for bearing troubles? How can they be remedied?

28. What is one of the causes for hot bearings on direct-connected units? What procedure should be taken to eliminate this trouble?

29. What procedure should be followed in repairing the bearings of an electrical machine?

30. What two general types of bearings are used in electrical machinery?

31. Show a method of constructing a bearing puller. Use sketches.

32. Describe several methods for removing a bearing shell from its housing.

33. What is the composition of the metal most frequently employed for bearing linings?

34. Name the steps in rebabbitting a sleeve-type bearing shell.

35. Describe the various steps in rebabbitting a sleeve-type bearing shell.

36. What conditions should be noted before melting the old babbitt from a bearing shell?

37. What solution is effective in cleaning bearing shells? What precautions must be taken in handling, mixing and cleaning bearing shells with acid solutions?

38. Describe briefly the tinning of a bearing shell.

39. What is the reason for preheating a bearing shell prior to pouring the babbitt? What effect does overheating the bearing have when preheating?

40. What material serves best to dam up the openings in a bearing shell prior to pouring?

41. How are bearing linings for small bearings usually poured? For larger bearings?

42. How should bearing mandrels be constructed? Illustrate using sketches.

43. Describe the setting up of a bearing shell preparatory to pouring. Make sketches.

44. Why is it desirable to have an entire bearing lining poured at once?

45. How can a mandrel be treated to prevent it from sticking to the babbitt metal?

46. What are some of the precautions which should be observed when pouring a babbitt lining?

47. Name the two groups under which babbitt metal may be classified.

48. What is the objection to using babbitt metal which has been overheated?

49. Is it advisable to use babbitt metal which has been melted from an old lining? Why?

50. What are the characteristics of a lead-base babbitt metal? A tin-base babbitt metal?

51. What are some of the methods employed to determine the temperature of babbitt metal?

52. What are some of the disadvantages in using the pine-stick method of determining the correct pouring temperature for babbitt metal?

53. What operation follows the pouring of a babbitt lining? Describe fully.

54. What points must be observed in fitting a bearing?

55. How can worn bronze bearings be restored to useful service?

56. What are the steps in rebabbitting a split bearing?

57. How can a split bearing be removed from its housing?

58. Describe a method of removing the babbitt lining from a split bearing.

59. Tell how to set up a split bearing preparatory to pouring the babbitt.

60. What are some of the requirements of a ladle used for pouring babbitt metal?

61. What are some of the advantages of ball bearings over sleeve bearings.

62. What are the three general types of ball bearings?

63. Why is lubrication of ball bearings necessary?

64. What precautions must be taken in assembling ball bearings on shafts? Illustrate.

65. Describe the application of the three general types of ball bearings.

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